

MEMOIRS
OF THE
GEOLOGICAL SURVEY
OF
INDIA.

OLS/44/RR2/E/RF

SALT HILL IN THE VALLEY AT BAHADUR KHEL
(Hill of Salt 200 Feet High.)

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44-2
R.R.2

VOL. XI, Pt. 2.

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MEMOIRS
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GEOLOGICAL SURVEY OF INDIA.

THE TRANS-INDUS SALT REGION IN THE KOHÁT DISTRICT, *by* A. B.
WYNNE, *Geological Survey of India: With an Appendix ON THE*
KOHÁT MINES OR QUARRIES, *by* H. WARTH, PH.D.

INTRODUCTION.

At the desire of Government, and under direct orders from the Superintendent of the Geological Survey of India, the Trans-Indus Salt Region was visited, and the country mapped during the working season 1873-74.

It had been represented that the map available was hardly adequate for the purpose of a detailed geological survey, but as no prospect appeared of obtaining one more suitable, shift had to be made with a MS. skeleton copy of part of the northern Trans-Indus Frontier Survey (dated 1852-53) by Lieutenant (now Colonel) J. T. Walker, Bombay Royal Engineers, published on the scale of two miles to an inch. A geologically coloured copy of the part used is appended.

Large portions of the original map are professedly unsurveyed, and its precision was not found sufficient to enable points to be closely fixed by prismatic compass bearings; for general marching purposes it answered admirably, and some of the larger stratigraphical features even were recognisable upon it, but the hill ranges are roughly shown, and the scale is far too small to admit of minute delineation of the geological boundaries, where these are complex. Indeed generally the structure of the

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country has been approximately recorded with a degree of accuracy greatly depending upon the limited means at command.

In consequence of some uncertainty as to the kind of information Government wished to obtain, and in order to furnish more comprehensive details, the assistance of Dr. Warth, of the Inland Customs Department (Deputy Collector in charge of the Mayo Mines at the Salt Range), was applied for from the conviction that his special experience of salt mines and mining in England, Germany and India, as well as his practical knowledge of the Cis-Indian salt, would aid in obtaining a better acquaintance with the salt deposits of this region, while in considering them from an economic point of view his services would prove highly advantageous.

Permission was given in compliance with this application, but Dr. Warth's duties at the Mayo Mines detained him till the examination of the ground was considerably advanced; however, by making double marches he was enabled to visit the important and largest exposure at Bahádur Khél, and subsequently to join in the inspection of a large number of the other salt localities.

A rapid reconnaissance across a part of this Kohát district by my colleague, Dr. Waagen, and myself in the year 1872 had led us to doubt the identity of the two salt series lying, mainly, one on either side of the river Indus. In the hope of clearing up this point, some time, previous to Dr. Warth's arrival, was devoted to visiting the old and unused salt localities and exposures from Láchee (Láchi) to Manzullí on both sides of the upper part of the valley of the Teeree Towey (Tíri Tauí) river; the geology of the ground being mapped *en route*. After this the Bahádur Khél and other western localities were examined, and then operations were carried eastward, until temporarily interrupted by a heavy fall of snow at Sundá Kullá Khél on New Year's Day, 1874. When the weather permitted work was continued in an easterly direction towards the Indus. In no part of the district thus traversed has anything been found leading to the abandonment of previous suspicions, and

although the age of the salt cannot be closely fixed for want of certainty as to the underlying strata, there is much to be recorded indicating that it is contemporaneous with the basal portion of the 'Subáthu' nummulitic series, and thus separated by many intervening geological periods from the ancient silurian or pre-silurian salt of the Salt Range.

The obscurity in which the origin of rock-salt masses is involved appears to have been felt by our most distinguished geological authors, and to have given rise to much diversity of opinion and theory as to the natural conditions conducive to the formation of this mineral. This is the more embarrassing, since it is one neither so rare nor so limited, as to exposure, that some satisfactory conclusions on the subject of its formation might not have been expected to result from the development of geological science. As to quantity, one German author (Karsten) places it after sulphur among the principal minerals formed in the crust of the earth, and other distinguished geologists (Sterry Hunt and David Forbes)* assign to it and its components a prominent place in the chemistry of the primeval world.

In the Kohát district occur what may be ranked among the largest exposures of rock-salt known to exist upon the globe, and while engaged upon the geology of such a region, attention was often attracted to the probable past, as well as the actual present, physical relations of the saline deposits. The record of the latter may throw no additional light upon the origin of the local salt-rock, for its general characteristics seem to be much the same as those of other salt deposits, if the size and purity of the great accumulations here be excepted. But the collection of observations is a necessary preliminary to accessions of knowledge upon obscure points, while it also affords the only test by which the correctness of conclusions can be tried.

Before proceeding, cordial acknowledgments are due for liberal assistance promptly rendered by Captain Cavagnari, Deputy Commis-

* Geological Magazine, Vol. IV, pp. 357 and 433, &c.

sioner, and R. Udney, Esq., Assistant Commissioner of Kohát; also to Nawab Sir Khwajah Mahomed Khán, Khattak, K.C.S.I., of Teri, in whose country the salt is situated, and for the aid afforded under order of the Deputy Commissioner by Alliár Khán, the Superintendent of the so-called mines.

The spelling of the names of places in the following pages has presented the usual difficulty, enhanced by the addition of the official mode. This would often differ so much from the names upon the map as to create confusion, so that the spelling of the latter has been retained, the official form being added wherever the difference is considerable.

A. B. WYNNE.

1.—PREVIOUSLY PUBLISHED OR WRITTEN INFORMATION.

The previously published geological information concerning the Trans-Indus Salt Region to which we could refer was very limited in amount. Nor is it likely that any such exists regarding a district so comparatively inaccessible of sufficient importance to influence the conclusions arrived at from independent observation on the ground.

Burnes.—A paper by Lieutenant A. Burnes, subsequently Sir A. Burnes of the Bombay Army, in the first volume of the Journal of the Asiatic Society, Bengal, refers to the Trans-Indus Salt Region. The author speaks of "a range of hills springing from the roots of the white mountain (Saféd Koh)" as part of the high lands of Kabul: this he describes as crossing the Indus at Harabagh (evidently a misprint for Kálábágh), and says it formerly figured in maps under the name of 'Jood,' but that it had received the more appropriate denomination of the Salt Range from the extensive deposits of rock-salt which it contained. He then proceeds to describe the Salt Range proper, or Cis-Indus, and its mines near Pind Dádun Khán, but makes no further allusion to the Trans-Indus workings.

At the time when this paper was written, the Punjab was not a British possession, and the Kohát Salt Region probably formed a part of Afghánistán or the border country. The author may have observed hills or mountains all the way from the Saféd Koh to the 'Hydaspes,' calling the Jhilam river by its old name, but modern geographers would perhaps hardly apply the word range as he does to several long groups of elevations parallel and otherwise, but having no such general and definite direction as might be inferred from his description. The proper continuation of the Salt Range appears to pass sinuously southward of the whole of the Kohát salt-bearing area.

Fleming.—Dr. Fleming, in one of his letters addressed to Sir Roderick J. Murchison, and published in the Journal of the Geological

Society of London,* makes one of his few references to the salt of this district. He differs altogether from Major Vicary in thinking the Salt Range salt connected with the tertiaries of Pind Dádun Khán, &c., (though what these may be, seeing that place is far removed from the last exposures of the tertiary beds, is somewhat doubtful), but he thinks "it probable that the Trans-Indus salt is found in similar strata."

We are not aware on what grounds this probability is based by Dr. Fleming, but if it be from personal observation, his opinion on the subject should carry weight, as he was so well acquainted with the saline series of the Salt Range.

Karsten.—The salt mines of the Kohát district are probably those referred to by Dr. C. I. B. Karsten as near (!) the Suféd Koh, in his voluminous *Lehrbuch der Salinenkunde* published at Berlin in 1846, (Vol. 1, p. 677). He describes the salt deposits as belonging to and forming a part of the Indian Salt Range, following apparently the paper by Burnes already noticed, an opinion which cannot be supported here.

In this volume containing so much information about the salt mines of all countries, there is an allusion to the Red Indians of North America perceiving the association of gypsum with rock-salt and thinking one a decomposed form of the other rock. It is curious to observe that the Patháns of the Kohát district also notice the recurrence of these two minerals together, and have been heard to call the salt of their country *Speenki ka bhat*, i. e., brother of gypsum.

Fleming.—Dr. Fleming, in his valuable reports on the (Cis-Indus) Salt Range (*Journal, Asiatic Society, Bengal*, Vol. XVII, p. 500, Nov. 1848; also Vol. XXII), makes but slight allusion to the Kohát salt, thinking it to be probably the same as that of the Salt Range, but does

* *Quart. Jour., Geol. Soc., Lond.*, Vol. ix, p. 189 (1853).

On the Salt Range of the Punjab—By A. Fleming, M. I. C., Assistant Surgeon, 4th Punjab Cavalry. Abstract of letters addressed to Sir R. Murchison. Read April 7, 1852, 1st letter from Murree, May 29, 1851; 2nd from Kutta Salt Range, July 16, 1852; 3rd, with specimens, &c., from Pind Dádun Khán, March 30th, 1852.

not give the reasons for his opinion, which, had so accurate an observer seen the ground, would perhaps have been different.

Oldham.—Dr. Oldham, Superintendent of the Geological Survey, paid a hasty visit to the district in 1864, and in his memorandum to Government on the Salt Range and parts of Bánnú and Kohát districts, mentioned the leading features of the quarries and the salt trade. The paper was not, however, intended to extend to the geological structure of the country or place of the salt series, and it will be seen from the following pages that the system in vogue then has progressed little towards improvement as regards the manner of working within the nine succeeding years.

Verchere.—Dr. Albert Verchere, in his paper on the geology of Kashmere, the Western Himalaya and Afghán mountains, likewise in the Journal of the Asiatic Society (Nos. 2 and 3, 1866, and 1, 2, 3, 1867), mentions some of the Trans-Indus salt localities with more reference to the geological age of the associated rocks. His description, however, of the Bahádur Khél exposure, while in one or two points correct, is likely to mislead. The thickness of the salt is *vastly* more than 50 feet. The red marl (*i. e.*, red clay zone) he misplaces below the gypsum; the dark brown sandstone at the base of the nummulitic rocks may belong to the red group, otherwise it is absent here, and although the place was searched for anything to represent the jurassic rocks coloured there upon his map, nummulitic limestones only were seen, and every section in the neighbourhood increased the conviction that the salt and gypsum series was directly succeeded by the nummulitic rocks, if not a part thereof.

Another, a manuscript "note on the geological formation of hills in the district of Bánnú and its neighbourhood" (1869 by the same author) has been met with.

In this there is a more extended reference to the part of the Kohát district under notice, but the rocks are mentioned (not always correctly) as if from the notes of a very occasional observer. Thus one would be led to infer that there were no nummulitic rocks between Láchee (Láchi) and Bahádur Khél, and that red marls of triassic age with small lenti-

cular beds of salt occur near the bed of the Teeree Towey (Tírfí Tātí) river, neither of which statements appears to be supported by facts.

The description of the section in the Soordag Towey (Súrdág Tauf) or Algud (that is to say, the Kurshru Algad) near Bahádúr Khél is anything but correct. The red zone which will be found described in the following pages is mistaken apparently for the red gypseous marl of the Salt Range and is called Trias! while a "thin bed of jurassic limestone" is stated to underlie a thin bed of nummulitic limestone. The short description of the section given by the author will be found to differ materially from the measured one at the same place detailed below. Káffir Kót crags are correctly stated, however, to be of conglomerate, though whether miocene or not is undecided, and the same rocks appear to extend, as described, thence to the Kooram, but "the wall of hills" north of Bánnú valley does not appear to have the steady north-west dip attributed to it, but rather to possess undulating inclinations, forming part of a general synclinal arrangement.

Balfour's Cyclopædia of India.—In this work there are references to the Kohát district, to the neighbourhood of Kohát containing numerous mines of different metals, of which "*Soná makhi*" (iron pyrites) and "*Pital makhi*" (? what) only are mentioned. A high range of neighbouring hills is said to abound with mines of coal; fluid bitumen (petroleum?), and momya (mumia) are stated to occur, and that the naphtha is in common use by the natives for lamps is asserted.

The authorities referred to for these highly exaggerated statements regarding the metallic and mineral wealth of the district are 'Mohun Lal's Travels, p. 358. Sch. Ad. Rec. of G. of I., No. ii,' (? Adolphe Schlagintweit, Records of Government of India), 'Masson's Journey, Vol. I, pp. 114 to 117, and Cunningham's History of the Sikhs, pp. 6, 7.' All efforts to trace these writings of Schlagintweit, if our reading be correct, have failed. Mohun Lal's travels have been thought open to doubt as to accuracy, and Cunningham's History of the Sikhs* has furnished no geological matter.

* Information kindly supplied by the Hon'ble R. E. Egerton, Financial Commissioner of the Punjab.

* *Other sources.*—Besides the above, there are doubtless other published sources of information, but even if accessible, it is unlikely that they would treat at any length of the geological structure of the country, or its mineral resources.

Mr. Carne, Collector of Salt Customs, 1850.*—A paper or report on these Trans-Indus Salt Quarries, &c., by Mr. Carne (1850) is referred to by Captain Plowden in his memorandum, and also quoted in Colonel Macgregor's *Gazetteer of the Frontier*.† The original paper was unfortunately not within reach to refer to, but appears to have been a tolerably accurate notice of some of the localities then worked; with an extract from a report by Mr. P. Melville, Secretary to the Punjab Government, regarding the management of the 'mines' under Sikh rule, when they were farmed to the Khán of Teeree (Tirí) for Rs. 6,000 per annum, a further revenue being derived by the imposition of various export duties.

Mr. Carne's description of the mode of working closely agrees with that by Dr. Warth given in the appendix hereafter, but he mentions the salt of a mine near Shukkurdurra (Shukardarra), of which the name is not given (it may possibly have been either Nandrukkí or in the Loon Nallah), as being "striped red and gray salt," associated respectively with marls of the same colour, whence he inferred a passage from the Cis-Indus red salt to the gray Trans-Indus salt. He evidently regarded the salt of both regions as the same, thinking that of this district "perhaps a little sweeter."

No such alternation as Mr. Carne describes of red salt underlying red marl or clay, and gray salt underlying marl of the same colour, has since been met with or observed at the places named above or in any other part of the district. As Mr. Carne speaks of the gypsum of Spina as chalk, his geological observation may not have been very close, or he may have mistaken detrital accumulations for rock *in situ*.

* Mr. Carne was murdered and is buried at Hurreepoor (Haripur) in Hazara, one march from Hasan Abdál.

† Information from Acting Secretary to Government, Punjab.

The Hon'ble R. E. Egerton, 1870.—Access has also been obtained to a MS. note by the Hon'ble R. E. Egerton, Financial Commissioner in the Punjab, regarding the salt of this region, dated December, 1870. In this the principal points of information, the names of some of the chief localities, prices, weights, and size of 'tubbis' are briefly mentioned, and some remarks made as to the duty charged beyond the Koorum (Kúram) river, the conditions as to trade, and the management of sales.

J. A. E. Miller, Esq., 1870.—A short note attached to this paper by the Secretary to the Financial Commissioner, dated also December 1870, gives a slight idea of the position of the salt excavations, mentions the five which are being worked, what tribes were permitted to take salt from each, and the rates of sales, also that the cost of excavation varied.

Captain Plowden, 1872.—A MS. memorandum (without its annexed map) on the subject of the salt resources of the Kohát district by Captain Plowden of the Punjab Commission was submitted for information by the Deputy Commissioner of Kohát. This is an ample and valuable record of the history of the so-called salt mines, of the method of working them, and the revenue derived therefrom, as well as numerous particulars relating to the fiscal statistics of the salt. It will be necessary hereafter in considering the economic aspect of the salt quarries to refer again to this memorandum containing much information, which it is to be regretted is not obtainable in a published form.

Other MSS.—Besides the MS. paper by Dr. Verchere previously mentioned, seventeen letters of various dates, and other papers, including a *précis* by E. O'Brien, Esq., (Acting Secretary to the Financial Commissioner), of records relating to the salt mines of Kohát have also been perused; none of these contain any geological matter; they refer generally to fiscal affairs, and were within reach of Captain Plowden when drawing up his exhaustive memorandum upon these subjects, the history of, and general information regarding, the Trans-Indus Salt Quarries.

2.—PHYSICAL GEOGRAPHY AND GEOLOGY.

It is as well to mention here that the Trans-Indus salt field or region under notice, does not include the salt seen

Situation. in the Lún (Loon) Nallah northwards from Kálábágh, on the same western or right bank of the river. This Lún Nallah salt has, notwithstanding the enormously broken and disconnected state of the immediately adjacent rocks, a much more intimate connexion with the Cis-Indus salt series, of which it appears to be the natural continuation, than it has with the rock-salt lying at the nearest point some twenty miles to the northward. Lithologically the salt of the two regions differs both in colour and texture as well as in general aspect. Nor is the association of adjacent rocks the same. At Kálábágh, displaced tertiary sandstones lie on one side of the salt, palæozoic and secondary limestones, &c., on the other, these latter beds never being seen in connexion with the numerous rock exposures occupying the large Kohát, or Khattak, salt region.

Excluding this (Lún) Nallah salt near Kálábágh, the area occupied by the Trans-Indus salt region is included within about a thousand square miles of country, extending from the British Frontier eastward to near the river Indus, and lying between Kohát and Bánnú, but nearer to the latter station, which is about eighteen miles distant in a south-westerly direction from the most southerly and westerly salt exposure at Súrdağ Pass.

Boundaries.—The natural boundaries of the salt-bearing country appear to be the Kúram (Koorum) river on the west and the Indus on the east; its political limits are, however, different, the 'red line,' supposed to indicate the British Frontier, excluding a large group of the Wazíri hills Cis-Kúram crowned by the mural rocks and pinnacles of Káffir Kòt.

British influence appears to be felt in the valleys wherever the land is at all fit for cultivation, but the hill ranges, far within the British Protectorate in the dominions of Sir Khwajah Mahomed Khán, are yearly

overrun in the *zemistan* or cold season by nomadic Wazíri Yági (independent tribes), whose flocks and rude black tents are shifted about as their own convenience or the exhaustion of the grazing may prompt.

These people are said to pay the Chief for their temporary occupation, to which they frequently return. They are a wild, largely made, athletic, but unkempt-looking race, contemptuously spoken of by the Patháns of the country as *Jánowars* (brutes), clad in rough goats' hair garments, and encumbered by but few possessions, besides their herds, their families, and their arms. They seem harmless enough, but even the shepherd on some rugged knoll, piping his *algoza* in orthodox fashion to his flock while it feeds, wears a formidable knife, or has his matchlock by his side, and it is not considered advisable to go among them unarmed, or pass the night in their vicinity. Notwithstanding this, and that they seem to keep separate from the people of the country,—with whom Sir Khwajah said they were frequently embroiled owing to cases of cattle-lifting—they were always ready to furnish water from the large earthen slung-bottles which they carry about, or to provide tobacco and *chilam* for the Sepáhi Guard.*

Ranges.—Within the area above indicated, the ground is occupied by four principal long and narrow chains of hills or continuous ranges, some of them having a length of over fifty miles, but varying considerably in width. These ranges with summit elevations of two, three, and four thousand feet above the level of the sea have an approximate east and west bearing, but diverge here and there as much as 25° both to the north of east and of west; the divergence of one range being followed

* On some occasions when belated they offered the hospitality of their encampments pressing me to spend the night in their tents, but this was declined, as the Nawab, Sir Khwajah, seemed anxious that I should return from the hills they occupied by daylight.

The fact of these Waziris roaming thus over the salt-bearing hills would have to be taken into consideration in any question regarding the watching and preservation of the mineral. The Salt Department officers assert that they do not now steal the salt, which, may be a consequence of its low value. For their own wants and those of their animals the very water which they drink, or which they have not to go far to find, may contain sufficient to suit their tastes. If the salt was dearer the case would probably be different.

in many cases by that of the others adjacent. They are all steep and rocky, rarely supporting any plateau-like ground, and there is hardly a ravine among the many by which their sides are furrowed that has not at least one precipitous 'bad step,' if the way is not altogether barred.

Valleys.—Between these ranges are broader valleys, the surfaces of which have a level or sometimes terraced appearance, but which are intersected by many abrupt and deep nullahs with vertical sides, or are sometimes broken by small hills taking characteristic forms from the stratification of the rocks. The largest of the depressions are those north and south of the salt region, the former a part of the Kohát Plain, the latter dividing the salt region from the lofty serrated ridges of the Shín Ghar flanking the Lowá Ghar Mountains to the south. Others lie along the sides of the Tírí Tauí river or its tributaries; but one large valley traversed by this river to the east, westwards towards Bahádur Khél, sends its drainage to the southward to form an affluent of the Kúram in the Bánnú basin.

Cross Drainage.—It is a peculiarity of the district that its drainage lines preserve hardly any relation to the run of its hills. The Tírí river crosses the central chain of hills, its tributary from Ismaíl Khél crosses the Jatta hills. The streams from the north of Káffir Kôt, as well as those from the Bahádur Khél valley, all cross the Súrdağ ranges, and waters from the Shín Ghar and Sakar Ghar mountains cross the range to the north by the Lákkona, Algad, and the Mittân Pass.

This conformation of the ground indicates that at the time when these streams began to run, the present valleys were all filled with tertiary sandstone and clay rocks; other features than any of those which now remain determining their courses.

General aspect of the country.—The general aspect of the country is wild, barren, and rocky, being almost bare of trees and supporting nothing worthy the name of jungle; patches of cultivation appear here and there in the valleys, but are scarcely sufficient to conceal the naked-

ness of the ground; and such is the scarcity of the food for animals that those who come long distances to the quarries for salt prefer bringing forage with them to buying it in the neighbourhood. The outline of the hills is uneven, sometimes strikingly abrupt; for instance, at the conspicuous summits of Sūkáwár, Húkaní, and Qund (the widower), Húkaní east of Shakardarra, or at the curiously castellated rocks west of Bahádur Khél called Káffir Kót—



Fig. 1. Outline sketch of summit of Káffir Kót or Lukkal Jooni Sir.

marked upon the map as a fortress! The natives said they had no knowledge of a fort having ever stood here, and if the mural cliffs were mistaken for one, it might well have been supposed to be the work of Titans (see below).

In certain cases the serrated outlines of the hills form a feature so marked that the kind of rocks of which they are composed and the position of the stratification can be assumed with considerable certainty even from a distance, while in others the arrangement of the irregularities of the ground is not less strikingly characteristic of the stratigraphical structure of the country.

Colouring of the country.—The colouring of the ground is often vivid, whole ranges taking a green tint, not from grass, but from the local colour of the rocks with which others of a bright purple hue are

strongly contrasted. Again, in the blood-red of some zones of clay varied by the white of adjacent gypsum, and broken by pale-orange or yellowish débris, the rocks themselves afford numerous changes to diversify the colour of a country which recalls the descriptions of travellers in High Asia, and which, when brightly lighted, backed as it is by the snowy ranges of Afghánistán, is often highly picturesque. The nummulitic limestone in the landscape has gray, whitish or orange tints, the rocks below are red, white, or gray, while the tertiary sandstones above often take a dark tint from the weather; greenish-gray, red, and purple alternations characterising the whole group.

Roads.—The ground, though rocky, presents few engineering difficulties of any magnitude to prevent the construction of roads, yet there is but one of these in the whole region, that from Kohát to Bannú, and this, as usual in the Punjab (excepting such roads as the Grand Trunk, the Murree, and a few others) is much out of repair.

The rocks where roads would be most likely to run are generally soft and easily cut through, while certain bands of hard limestone afford an excellent material for building or metalling, and some more earthy bands in the lower part of the limestone (not, however, noticed exactly within this part of the Kohát district) might probably furnish a valuable hydraulic cement.*

There are no wheeled conveyances in the country as a rule, but until advancing civilization might bring them into use, good bridle roads might be constructed as easily as in many other countries, and would prove specially valuable for the salt traffic which now finds its way by devious tracks over difficult passes and through defiles without the least aid from engineering science.

* In case of any trial of these clayey limestone bands for this purpose, the stone would be found very accessible in the nallah, by which a track leads northwards to the village of Turkhobay, latitude $33^{\circ}35\frac{1}{2}'$ north, longitude $71^{\circ}52\frac{1}{2}'$ east.

Physical features.—Here as elsewhere the physical features are chiefly the result of meteoric denudation, connected as a matter of course with elevatory forces, but less strikingly here than in other places, for the irregularities of the ground depend so palpably upon the harder or softer texture of the rocks that differences of form would probably have shown themselves under erosion without much reference to the degree of elevatory force exerted; still the positions of the rocks have as usual had a governing influence in deciding the shapes which the ground has assumed. Soft sandstones, when nearly horizontal or slightly inclined, have taken the forms of, or approximate to, abruptly scarped or tabular hills—the same kind of rocks at high angles forming saw-edged ridges; while all the chief ranges owe their height and character to hard zones of nearly vertical limestone of much inferior thickness, but greater strength than the bulk of the associated rocks.

Large exposure of salt.—One physical peculiarity, is the way in which the salt rock occurs in naked exposures, so much more frequently and of so much larger size than in the Cis-Indus or Salt Range proper, leading to the enquiry whether this salt has or not a different solubility (not likely to any considerable extent), or whether the humidity of the atmosphere or rainfall varies in the two regions. The salt of both regions being exceptionally pure, is liable to rapid solution by fresh water, but in the salt of this region the frequently well marked stratification is sometimes defined by a slight earthy admixture of fine gray clay, (not, however, sufficient to interfere with the value of the mineral,) and this may have an effect upon its manner of exposure in masses. It may be observed too that less care is taken to preserve the worked salt here from rain than in the Salt Range, the carrier in wet weather protecting himself with his blanket rather than his load of salt, and not seeming to regard the latter as likely to suffer much: the salt here, however, being much less highly priced than it is on the other side of the Indus, this may have an influence in making the buyers careless.

Rainfall.—The average annual rainfall for the past ten years at the stations nearest to the two salt-bearing tracts has been as follows:—*

<i>Frontier.</i>			<i>Salt Range.</i>		
Bánnú ...	...	11·26 inches.	Shahpúr ...	...	15·55 inches.
Kohát ...	...	17·12 inches.	Jhslam ...	...	24·24 inches.
Average ... 14·19 inches.			Average ... 19·895 inches.		

(The returns at Ráwál Pindí are only recorded for the past seven years, giving an average of 19·58 inches).

From these figures it will be seen that more rain falls in the Jhslam and Kohát neighbourhoods than in the others, but if Bánnú and Shahpúr be taken as the two nearest stations, respectively, to these different salt regions, there appears to be an excess in the Cis-Indus rainfall of about three inches yearly, which may have some influence in concealing or removing the salt there more than in this region.

Meteoric denudation leaves marked traces upon some of the rocks of this district, particularly those of chemical origin,—the limestones, gypsum and salt; the action of the salt-charged water from the hills upon the soft sandstone generally occupying outer or lower situations is also powerful. Many of the saline streams cut flat rocky bottoms from the beds, no matter in what position their stratification rests, and the stone at the sides of these, liable to alternate saturation and drying, rapidly disintegrates, crumbling to the touch.

The registers of rainfall as given do not show whether there may be a difference as to its periodic occurrence in the two places. The season during which the country was examined was one of exceptional cold and wet, rain having fallen sometimes twice in each month. Before this there was a long period without rain, and the powdery weathered portion of the softer rocks seemed only waiting to be washed away, while the whole country exhibited quantities of the white efflorescing salts,† some-

* From data supplied by the Deputy Commissioner of the District.

† Chiefly composed of sulphate of soda with a little common salt and a trace of carbonate of soda (Dr. Fleming's 1st Report, Salt Range, J. A. S., Bengal, November, 1866, p. 525). Sulphate of soda, sulphate of lime, chloride of sodium, and carbonate of soda (Dr. A. Verchere, J. A. S., Bengal, 1867, p. 40).

times here called *shór*, but known elsewhere as *kuller* or *toor*. This disappeared after rain had fallen, but was to a certain extent renewed again in the few following fine days, both on the sandstone rocks and superficial deposits.

Subterranean drainage.—It may be doubted whether all the water derived from the atmosphere over this district finds its way to the superficial streams and thence to the Indus. The steep forms of the ground would show that this must be the case most commonly, but where the superficial form is favourable, the occurrence of large crater-like pot or swallow holes, in very numerous localities, caused by dissolution of the salt, shows that under-ground channels exist. Springs of saline water at the bases of some of the ridges will be readily accounted for in this way, but the percolating water may be much in excess of any which comes again to the surface within the district. Where it may do so is very doubtful, and it seems strange that the whole drainage of so large a salt-bearing area, most of the streams in which are saline, should have so small an effect as to be unnoticeable to the taste in the waters of the Indus below this region, and but slightly so even in the larger streams of the district itself, such as the Tírí Taní, the water of which has more frequently the predominating taste communicated by the *shór* of the country * than that of water saline from edible salt.

PHYSICAL GEOLOGY.—As may have been gathered from some of the foregoing remarks, the physical geology is closely connected with the physical geography of the district. The ridges, ranges, and valleys, notwithstanding some extraordinary complexities (which will be pointed out), may be considered as long waves in the strata, many of which might not inaptly be compared in form to the breaking rollers of a heavy surf. The anticlinal portions of these waves show every sign of intense lateral pressure in north and south directions, and the forms of all have been greatly modified by erosion.

* Called *kárá paní* or *kaora pani* all over the country in contradistinction to *máa paní*, sweet or fresh water.

The cross drainage of the country, already alluded to, shows that these ranges and valleys, instead of merely directing the flow of the meteoric waters, as would at first appear, are themselves but the result of its powerful and long continued abrading force.

It is clear that the gaps through which the rivers now escape across these ridges must have been commenced under a very different state of things, at a time when the ridges, as such, did not exist, these and the whole of the present surface being then buried beneath the soft strata of the plains.

There would seem to have been a depression over the valley of the Tírí Taúf from an early period, in gravitating towards which the streams found it easier to deepen their former channels than to force a passage through masses of the tertiary sandstone series towards either the Indus or the Kúram. Notwithstanding this, the greatest effect of the meteoric water in reducing the general level of the country was undoubtedly produced upon these softer tertiary sandstones, &c.; the harder limestone and beds supported by it being left in relief, the present features of the ground were thus carved from the mass.

Structure of the ground.—Perhaps the easiest way to realize the structure of the ground is to follow the more open and less disturbed curves of the sandstone and argillaceous rocks occupying the valleys. These, with many minor undulations, are found forming troughs, the strata at the sides rising steadily, where not interrupted by dislocations, towards the anticlinal ridges, and re-appearing with the same general character in the valley on either side. From this it would follow that the rocks of the ridges must be older, and as these, largely, if not entirely, belonging to the same great tertiary formation, pass conformably beneath the beds of the valleys, the simple alternation of anticlinal and synclinal curvature might be expected to succeed. The case is, however, different, the strata rising steadily towards the ridges become steeper, vertical, and ultimately overthrown, so that along the sides of nearly all

the ranges, instead of finding the sandstones of the valleys regularly underlaid by older layers, they are, where not actually faulted, very commonly inverted, being inclined at strongly marked angles the wrong way, as it were, dipping towards the axes of the anticlinal ranges, and in some cases absolutely reposing for large spaces, in inverted horizontal order in such a way that the lowest rock of this portion of the series, the nummulitic limestone, has been found (just outside the limits of the district mapped) for the width of more than half a mile, forming an undulating horizontal cap, resting upon rocks which are absolutely newer than itself !*

* The section here close to Koteyne on the Kohát Tauf is so expressive of the complications of the district that it is given below. The inversion extends along the strike for more than seven miles.

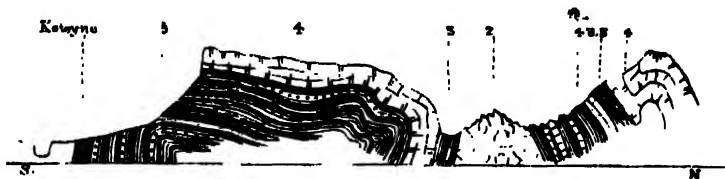


Fig. 2. Section near Koteyne on the Kohát Tauf, about one and a half miles.

2. Gypsum and gypseous series. 3. Red clay zone. 4 (a). Lower nummulitic. 4 (b). Nummulitic limestone. 5. Tertiary sandstone series.

The beds on both sides of the gypsum are not the same exactly, there being but some 25 feet of purplish red clay seen to the southward, containing a flaggy purple band, a green band with malachite stainings or films, and becoming selenitic for 4 feet near the gypsum, with thin fibrous limestone layers having cone-in-cone structure. To the north, these latter layers are much more developed, overlying a bed of greenish shale with concretionary yellow marly nodules of limestone. The cone-in-cone beds contain lenticular bituminous patches, smelling strongly of petroleum. Greenish shales are more largely present here also, and contain flaggy limestone layers, with traces of plant fragments in the clays or shales. These beds are succeeded on this side by red clays which immediately overlie the gypsum southward, but are more largely developed here. The thin and shaly lower part of the strong nummulitic limestone succeeds to the southward, overlying the more solid limestone in inverted order, this limestone itself resting upon the tertiary sandstones as shown in the sketch, though really the latter are the newest beds.

. There is often a startling similarity in these inverted sections to a true ascending instead of a descending order, and were it not that within the district at the extremities of some of the anticlinal ridges the rocks are found in their proper or normal order, instances would have to be brought forward from various external localities to show that the ordinary appearance of the sections along the flanks of the hills is fallacious.

The abnormal relations described are not limited to one side of each anticlinal ridge, but seem to be, on the whole, more largely developed along their southern aspects, and though no persistent regularity of the inversion points strongly to overthrow from the north, the balance of evidence may slightly indicate a preponderance of force or thrust from that quarter.

From what has just been said, it will be seen that, at all events, in the country under notice, the great regularity and steady dip to the north-west asserted to exist in this region (Verchere, Jour. As. Soc., Bengal, 1867, p. 92,) partakes somewhat of an imaginative character.

In considering the general structure of the country we have thus a large series of sandstones and clays overlying a comparatively narrow but strong zone of nummulitic limestone, both forming open synclinal troughs, between which rise long, narrow, approximately east and westerly anticlinal ellipses, the forms of the latter being well defined by the limestone zone coinciding with the hill ranges. Down to this limestone, order, though complicated, exists, but below it disorder, and structural obscurity is the rule, the interiors of these ellipses being occupied by disturbed soft strata of clay or shale and sometimes sandstone, by quantities of gypsum and by harder amorphous or distinctly bedded masses of rock-salt.

The latter is the lowest rock known with any certainty to exist in the district. Such is the state of confusion and concealment however, that the salt might well be locally absent, or lower clays exposed.

The overlying gypsum is frequently well stratified, but its contortion and dislocation diminish its usefulness in explaining the internal

structure of the hills, though where the sections are clearest, its stratification and that of the rock-salt, which is frequently well marked, display sufficient conformity with the general anticlinal structure, however disturbed, to warrant the conclusion that a conformable sequence exists throughout from the salt up to the newest sandstones of the valleys.

System of disturbance.—The system of disturbance producing the approximately east and west anticlinals and synclinals is common to other parts of the Upper Punjab, though here complicated not alone by inversion, but by faulted dislocation, coincident with the resultant features, and usually manifest near the bases of the hills, as if original lines of weakness had initiated the curvature which occasionally relieved itself by fracture of the strata. All these lines of disturbance assume a rude parallelism, and none would appear to radiate from the centre of an area of depression.*

As a probable consequence of the relations between elevating forces and the resistance to be overcome, most, if not all, mountain chains are narrower than the plains from which they rise; so the anticlinal ridges here, regarded separately, are narrower than the valleys, still sufficient irregularity exists in this respect to suggest that the circumstance may be accidental.

The structure of the ground described can of course be most accurately known, only within reach of observations over the surface, yet it may be fairly inferred for concealed portions of the synclinals; what the forms of the denuded portions of the hills may have been it is of course difficult to conceive or restore where opposite sides of the anticlinal folds exhibit stratification which would diverge instead of approaching over their axes. The most natural supposition seems to be that the arches produced by lateral pressure were once much wider, and that either continued or repeated compression in the same direction

* Considering the faults and flexures as produced by horizontal force, the district would exemplify "a series of anticlinals and synclinals interspersed with faults." See paper by Revd. O. Fisher, *Geol. Mag.*, 1874, p. 65.

forced the 'springs' of the arches towards each other till the upper portions under this pressure, combined with that of their own weight, assumed a position reversing the natural order of the beds, in those places where planes of dislocation did not allow of one segment of a curve becoming displaced. That the arches were complete and at one time covered by some at least of the newer sandstone strata is suggested by the cross drainage of the country and proved by the fact of considerable fragmentary portions of the latter rocks once crowning an arch, being now found located among other disordered masses within an ellipsoid of the limestone, nearly beneath their original situations.

Though the hills are not of great height, seldom exceeding 2,000 feet above the valleys where such pressure has been exerted, the structure of the ground points to a former much greater superficial area, occupied by the rocks, quite as well as if they had gone to form higher mountains.

Former greater superficial area of rocks.—If the curves of the strata be followed and even roughly restored to horizontality, it may not be too much to assume that the strata of the district under notice would before their contortion have reached in a north and south direction at least one-third further than they do at present, but the estimate can only be approximately made.

This district differs from neighbouring ones eastward in the greater variety of the rocks exposed by these convolutions of the strata; hence it may, not unreasonably, be presumed that the floor of the country, so to speak, stands generally higher (for instance, than that beneath the Potwár region), and is gradually rising perhaps in a westerly direction, thus bringing the nummulitic limestone and beds below it more within reach of the influences by which they were exposed. Either this, or a general diminution in the thickness of the overlying sandstone and clay rocks, would seem to be the case, as all the divisions of the latter recognised to the eastward are found here, and both regions are highly contorted.

III.—GEOLOGY.

The rocks of the district, of which some account is now to be given, may be classified in their natural order of superposition as follows:—

	SUPERFICIAL DEPOSITS	...	{	Diluvium, sandy river deposits, sand, recent conglomerate, and detritus.—Thickness irregular.
NARUN ?	UPPER TERTIARY SANDSTONE, &c....	{	{	Soft gray sandstones and clay conglomerates and boulder or pebble beds; 800 to 1,500 feet.
	MIDDLE TERTIARY SANDSTONE, &c.	{	{	Gray and greenish sandstones and drab or reddish clays, with bones and fossil timber; 2,000 to 3,000 feet.
DUGHAI	LOWER TERTIARY SANDSTONE, &c. (OR MURREE BEDS.)	{	{	Harder gray and purple sandstones, bright red and purple clays, slightly calcareous and pseudo-conglomeratic bands. Bone beds occur below, also obscure plant fragments, apparently exogenous fossil timber, and in places near the base a thin layer of strongly ribbed bivalve shells, in bad state of preservation; 3,000 to 3,500 feet.
SUBATHU (EOCENE)	UPPER NUMMULITIC	...	{	Nummulitic limestone, <i>Alveolina</i> beds more shaly, limestone with a cherty band, contain <i>Gastropod</i> sections, several <i>Bivalves</i> , &c.; 60 to 100 feet.
	RED CLAY ZONE.	{	Red clay, lavender coloured at top with <i>Nummulites</i> in one locality; one or two sandstone bands near top contain fossil bone fragments; 150 to 400 feet.	LOWER NUMMULITIC
		{	Sandstone with <i>Nummulites</i> or thick greenish clays, and limestone bands, locally developed below or at place of the red clay zone; 100 to 350 feet or more.	
(Observer).—The red clay zone is more extensive than the lower nummulitic beds.				
NUMMULITIC (EOCENE) PROBABLY.	GYPSUM	...	{	White, gray, and black gypsum with bands of dark gray clay or black alum shale, gypsum, sometimes impregnated with petroleum or bitumen, alum shale generally so; series, 50 to 300 feet.
	ROCK-SALT	...	{	Rock-salt associated with beds of clay and sometimes earthy impurities. The upper part bituminous and base unseen. 800 to 700, or 1,300?

Rock-Salt.—Taking the rocks of the foregoing list in the order of their age, the rock-salt, being the oldest, claims attention first.

As a rock largely exposed.—This mineral occupies an important place as a rock in some parts of the district, notably in the vicinity of Bahádur Khél, where it forms high detached hills, cliffs, and naked exposures on both sides of a small stream valley (see Frontispiece) for a distance of four miles in an east and west direction, having a maximum width exceeding a quarter of a mile or 500 yards.

For four miles more to the eastward it is slightly concealed by débris or visible in many places, the sunken aspect of the ground full

of large crater-like holes proving its presence now or formerly immediately beneath, while throughout the district it is frequently exposed, generally forming precipitous outcrops within the elliptical boundaries of the nummulitic limestone.*

The exposures vary in size from the enormous one at Bahádur Khél to others of a few feet and less.

Colour and character of the salt.—The salt possesses a characteristic whitish or gray colour all over this region, its texture varying from a highly crystalline mass, the most common form, to a somewhat earthy salt intermingled with some blue or grayish finely divided clay. It often contains blotches of transparent crystalline salt (*shishi nimuk* of the natives), giving it a conglomeratic appearance and rarely minute fragments of gypsum projecting from the weathered surface of the rock.

The earthy impurities are most common in the western part of the district, where the largest exposures of salt occur, but even here only a few subordinate bands are considered unfit for working, nor is it at all certain that if such large exposures of salt occurred elsewhere, these slightly earthy bands would not be found, for in some of the eastern exposures, as at the Zaino quarries, there are also layers of salt less pure than usual.

The impurities at both ends of the district, slight though they be, would have some importance if they might be taken as any indications of original limits of the deposit in these directions.

Much the greater portion of the salt is remarkably pure, and, so far as is yet known, without a trace of contained or associated salts of another class, such as the potassa salts of greater economic value.

In the eastern parts of the district, besides the foreign matter previously noted, the uppermost portion of the salt, which is also the most impure, is frequently bituminous and sometimes slightly pyritous, this

* The various places at which rock-salt is seen or known will be mentioned in detail further on. See Part II and Appendix.

salt and the adjacent gypsum smelling strongly of petroleum. The bituminous salt prevails, however, only for a few feet from the upper surface of the deposit, though layers of bituminous or fœtid clay may be found apparently in the body of the salt-rock, through large portions of which, even when seemingly pure and crystalline, freshly broken samples have still a faint odour of naphtha or petroleum, specially observable at Jatta.*

Composition.—Specimens of the salt sent to the Laboratory of the Geological Survey of India have been examined by Mr. Tween with the following results. It appears that the better portion of the Bahádur Khél salt contains less sulphate of lime (gypsum) than the purer looking salt from Málgin, while there is but little petroleum present in any, that little being, however, often very perceptible to the senses.

Clean salt from Bahádur Khél had this composition—

Chlorine	59.52	} 100.
Sulphuric acid	...	...	...	...	1.5
Lime	...	...	...	...	1.06
Sodium	...	...	...	...	37.47
Insoluble	...	...	...	...	.45

The relative characters of other salt specimens from the district may be seen from the following table :—

	1	2	3	4	5
	Earthy salt from Bahádur Khél.	Good salt, bituminous, Jatta.	Upper black salt, Jatta.	Another specimen, Jatta.	Good salt, Málgin.
Loss on heating	...	2.3	0.4	0.8	...
Soluble matter	...	97.8	97.8	99.2	99.75
Insoluble	...	10.0	1.8	.6	.25
	100	100	100	100	100

* Rock-salt frequently contains admixtures of bitumen, clay, &c. : Cotta, "Rocks classified and described," p. 352.

On this subject Dr. Warth remarks:* "the analysis seems to justify expectation. The natives assert the Kohát salt to be less saline to the taste than the Cis-Indus, and it appears they are right as far as the admixture of foreign salts is concerned; it is the latter which give a more intensely saline taste to the rock-salt of the Cis-Indus mines." Annexed is a comparative table of the chemical constitution of the Kohát salt as compared with that of the Mayo Mines in this respect.

				No. 1.	No. 2.	No. 3.
				Kohát salt analysis above.	Pure trade salt, Mayo Mines.	Impure waste salt, Mayo Mines.
Insoluble matter	..	..	..	0.5	Trace.	1.0
Sulphate of lime	..	...	...	2.5	0.5	2.5
Magnesia	...	}	...	0.0	1.7	2.5
Calcium	...					
Sulphates, &c.	...					

"From this it is seen that the Kohát mineral contains no foreign salts at all, while the best Cis-Indus salt contains almost 2 per cent. Further, the Kohát salt contains a considerable amount of sulphate of lime and of insoluble matter, approaching in this respect the bad salt (No. 3 above) of the Mayo Mines. Thus the salt of Bahádúr Khél is purer than that of the Mayo Mines as regards foreign salts, and less pure as regards insoluble matter and sulphate of lime."

Stratification.—Except where the salt is very massive and crystalline, its stratification is generally well marked, though sometimes concealed in the eastern quarries partly from the homogeneous structure and partly by the marks of the miners' picks. The slight admixture of clay at the western exposures favours the recognition of the lines of bedding which are frequently as clearly seen as in any other rock, and which also determine the local method of working.

* MS. letter, May 1874.

Thickness.—Using these bedding planes and their inclination by which to calculate the stratigraphical thickness, the maximum thickness of the salt-rock in one part of the Bahádur Khél exposure is thus found to amount to no less than 1,230 feet in round numbers. So that even making a large deduction for any slight alterations in the angles of inclination to say the salt has here a visible thickness of one thousand feet is apparently considerably within the mark, for the section giving this thickness ends both ways in salt. Even on the spot it is difficult to realise this great thickness as being true. Yet almost every bed from one side of the valley to the other might be counted, and their steep northerly dip is palpable. In mentioning the detailed features of this locality, some facts will be noticed which might strengthen the suspicion that an exaggerated appearance of their original thickness obtains, but this could only be reduced upon supposition, while, however produced, the measured thickness is a fact. Both east and west of this measured thickness, the salt has an anticlinal structure reducing its bulk, but here it is also much less exposed. In other parts of the district large thicknesses of one, two, and three hundred feet of salt beds without any alternations of unworkable salt are exposed, but in no case can it be said that the bottom of the deposit or deposits is seen.

Manner of exposure.—The salt is here associated with gypsum, as is commonly the case, the gypsum also, as in perhaps a large majority of instances where both are present, overlying the salt. This gypsum being less soluble by rain water occupies an enormously greater superficial area than the salt; and the association of the two perishable rock minerals with masses of soft gypseous and other clays within the anticlinal curves of limestone in situations subjected once to great lateral pressure, and subsequently, from their superior elevation, favouring the action of the denuding agencies (to which they are still exposed), is doubtless the reason why the rocks in the interior of the nummulitic ellipsoids present such a broken, confused, and concealed state of irregularity. Amidst obscure masses of gypsum covering and undulating over

broken hilly ground or disturbed masses of clay, the soft strata below the nummulitic limestone, or under quantities of superficial débris, deeply cut ravines sometimes expose the salt along their precipitous sides for considerable distances. In other places the local fall of a portion of the clay and débris at the head of a small nallah may allow the salt to be seen, the action of rain water sometimes tending to enlarge the exposure, sometimes to cover and conceal the salt again.

In most places it presents vertical or approximately vertical faces from the rapidity with which it yields to the action of the atmospheric water, which also cuts it into pillars, spires, and strangely fluted or systematically grooved forms, with sharp edged dividing reliefs, the hollows all leading up to points. At some favourable situations where the salt contains a percentage of clay, the slow solution of the former leaves this behind, and thus the rock-salt becomes covered by a heap of dark gray saline earth forming a coating which must ultimately act as a protection to the mineral beneath.

Joints or such divisional planes are rare in the mass, yet some strongly developed, approximately horizontal, joints have been observed, traversing salt escarpments or outcrops.

Strata that may underlie the salt unknown.—The exposures of the salt are not such as to enable any satisfactory observations to be made with regard to the possibility of some of the soft associated strata really underlying it. In but one instance did the quarrymen admit that this had ever been penetrated by their working. The statement was founded much on hearsay, and to the effect that below the salt at one of the Jatta quarries '*sheenkow*,' the ordinary gray, gypseous clay found with the gypsum had been reached. There is perhaps some probability that in so disturbed a region, if there existed any strong zone of gypsum or harder rock immediately below the lowest visible salt, it would make its appearance in one locality or another, but there being absolutely no data to limit the depth of the nearly horizontally bedded salt over a great portion of the ground in which it is seen, speculation as to what may underlie it becomes involved in the greatest uncertainty.

Continuity of the salt.--Where the ground is so much obscured, it is of course difficult to say whether soluble strata of salt may not have been entirely removed by infiltration of fresh water from certain localities, and thus it becomes impossible to determine the presence or absence of a continuous salt zone throughout the whole district. For the same reason it may not be presumed that where the mineral is elsewhere exposed, it has the same great thickness which it exhibits at Bahádur Khél, and it is quite useless to attempt to speak with certainty of the extension of the salt even from one exposure to another when these are separated by any considerable distance, the probability that it does extend being of course increased as the exposures approach each other.

Difference between this salt, that of the Salt Range, and other salts.—The differences between the general characters of the Kohát salt and that of the Salt Range are vastly more marked than the similarities to be found between them, and the associated series in the two districts. Among the former may be pointed out that the salt-rock here, wherever traceable connectedly for any distance, forms one enormous stratified deposit from top to bottom without alternation, with sharply defined bands of (*kuller*) saline clay intervening between thick zones of purer salt, as in the Salt Range. Another marked difference is that of colour, nothing resembling the red or pink Cis-Indus salt having ever been observed in this district. The bright-red gypseous marl of the Salt Range has no representative here; the clays most closely associated with the salt and gypsum being gray like the salt itself.

A deep blood-red, rather than scarlet, zone of clay in this Kohát district, entirely different from that of the Salt Range, and sometimes by its washing down discolouring the débris overlying the Kohát salt and gypsum of a reddish tinge, occupies so far a somewhat similar place, that in both cases the salt is succeeded by gypsum and the latter by a soft red zone, but in the Salt Range the red marl and gypsum are more closely associated, and may even alternate in thick zones, while the red clay here exhibits plainly a distinct horizon of its own and contains

gypsum only in thin cross veins or flaggy layers close to its junction with the mass below and in no considerable quantity. There are other distinctive characters besides to be mentioned in their proper place, and the slight similarity, so far as position, does nothing towards establishing any degree of identity between the deposits.

The whole aspect of the salt here is also different: none of the compact variety used along the Salt Range for turning into ornamental utensils occurs here, nor any furnishing the fine large cubic crystals which make up whole beds at Kálábágh. The only approach to this is in the blotches of *shishí nimuk*, from which, when of some size, beautiful crystals may be cleaved exceeding in transparency those of the last named locality. The absence of foreign salts here, which have been found disseminated and as a separate deposit in the Salt Range salt, is another point of dissimilarity; as is also the impreguation of some of the salt here with mineral-oil, a feature not observed in that locality, though bituminous shale and clay, much associated with the gypsum here, occurs there also in one small band or deposit, with the gypsum of the Kheura gorge.

In a word, the salt deposits of the two regions are so strikingly unlike that even small samples, if not reduced to powder, are declared capable of being sworn to with confidence by those whose duty it is to prevent the Kohát salt from entering the country on the other side of the Indus.

The rock-salt of Persia lying far to the west of this district has probably no close connection with that in Kohát, as the Persian gypseous series, (and the salt) *overlies* the nummulitic formation, (Blanford, Quar. Jour. Geol. Soc., Lond., Vol. XXIX, p. 501).

The salt of the once famous island of Ormuz in the Persian Gulf is of rather uncertain, but possibly early tertiary, age, and in its manner of occurrence associated with volcanic rocks, (dolerites, trachytes), and micaceous iron, presents no analogy with that of the Kohát district.

The Mundi salt in the flanks of the outer Himáláyá is apparently different from this, both in its impure earthy composition, in having no associated gypsum, and in the age of the rocks amongst which it occurs.*

Of other rock-salt exposures in the Himáláyá, in High Asia, and the neighbourhood of the Caspian Sea mentioned in Dr. Karsten's volume, (previously alluded to), little is known, but it is worth noting his recording the frequent occurrence of petroleum with that of the latter locality, taken in connexion with the bituminous impregnation of the salt here: indeed, he seems to argue from the existence of earth-oil in Italy that rock-salt would eventually be found in the same localities.†

Age of the salt.—The attempt to fix the *precise* age of the Trans-Indus salt is beset with difficulty on account of the absence of palæontological evidence near it from which to reason. It has been stated to differ entirely in itself and its immediate associates from the Cis-Indus salt, but when the whole of the adjacent sections are examined the disparity increases. In the Salt Range the salt series itself is one of the most constant features of the geological sections. Another less constant group is the nummulitic limestone, but between these at various places are interposed silurian, carboniferous, triassic, jurassic, and cretaceous formations, besides unfossiliferous groups which have only received local or provisional names. Even where the Salt Range series is least ample,

* Mr. Medlicott's opinion that this salt is associated with the Krol (Trias?) rocks is recorded in Geological Survey Memoirs, Vol. III, pt. 2, p. 60, etc. Dr. Warth's notes made at the place coincide with this view, but Mr. Theobald, who has also visited the deposit, has seen some reason to believe that it does not belong to the older series, but is of eocene age, when it might represent that of the Kohát district. Dr. Jameson's attempt at correlation of the Mundi and Salt Range salt is open to very considerable doubt (Jour. As. Soc., Beng., Vol. xii, 1843, p. 218), and is unlikely to be correct.

† In connexion with this subject we also find that "a very rich oil-wall was just discovered in Nauchalts, Russia, on the shore of the Caspian Sea." After boring 120 feet oil was found, which flowed for 20 minutes. This was followed by a deafening noise accompanied by a slight earthquake, after which a jet of clear water, *very saline*, burst forth with great violence, running for nearly half an hour. Since then from 1,500 to 2,000 pailfuls of oil have been drawn out.—Colliery Guardian, April 7th, 1866, quoted in 'Geological Magazine,' Vol. III, p. 287. *Italics ours.*

the salt and gypsum lie buried below some five thick palæozoic and mesozoic groups (from the base of the nummulitic downward), forming many hundreds of feet of rocky strata. Here in the Kohát district, however, the salt and gypseous series is only separated by a band of red clays, averaging about 250 feet, from the fossiliferous basal beds of apparently the same nummulitic limestone as that of the Salt Range series. No unconformity is observable in the sections here, nor is there any established in those of the Salt Range above mentioned either.

Further than this there is not alone presumable parallelism of position from the Kohát nummulitic series downwards, but in tracing the boundaries of the formations at least one thin band of salt was found, separated by a thicker layer of dark bituminous gypsum from the mass of the salt below. Again, the gypsum was found to alternate with limestone beds or thin layers in some places, and even above the red clay zone succeeding the mass of the gypsum, strong bands of the latter were found locally interstratified with the basal portion of the nummulitic series. These alternations would appear to indicate a long period of tranquil conformable deposition extending from that during which the salt was formed up to the time of the nummulitic limestone, a period in the course of which the conditions necessary to such alternations were partially or locally recurrent.

Throughout this lower part of the Trans-Indus series the evidence of organic existence is scanty and uncertain. The fine gray clays associated with the gypsum here and there contain small fragmentary traces of grass-like plants, and a few obscure shell impressions occur in some of the accompanying limestone layers close to the gypsum; while further up in certain bands of sandstone near the top of the overlying red clay zone some broken fragments of bones have been detected, but none of these afford any grounds on which to separate the saline lower part of the series from the nummulitic rocks above.

Dr. Verchere, while leaving the age of this salt undecided, seems to have followed others in assuming that it formed a continuation of that

of the Salt Range, and on the evidence of some shelly limestone layers containing minute unrecognisable fragments, near Bahádur Khél, at the base of the nummulitic group, has apparently considered the jurassic formation to be present, and has introduced a colour to represent it on his map at that place, (paper already quoted, Jour. As. Soc., Beng., 1867, p. 26).

A careful search for jurassic beds at the locality only resulted in the discovery of some thin limestone full of broken shells, apparently of oysters, which may be those Dr. Verchere mentions. Such beds are not uncommon in other parts of the district among the inferior layers of the nummulitic limestone and underlain by other lower beds of that formation containing *Nummulites*, &c., sometimes in abundance. Hence the introduction of an older formation than the nummulitic, on what may have been no better grounds than mistaken identity, has been avoided.

Failing the discovery of any clue leading to a more satisfactory conclusion, we are forced to draw upon probability in the effort to assign a place geologically to this Trans-Indus salt series.

To follow the vague indications of early writers, and assume that this salt series is an extension of that of the Salt Range, involves the acceptation as facts, that the salt and gypsum here are not more recent than silurian; and that in the Salt Range region now at a distance from this of say thirty* to ninety miles, (while the salt series was being gradually covered up by seven different thick palæozoic, mesozoic, and Cainozoic formations) conditions here underwent little change, and nothing was deposited after the main body of the gypsum to mark the lapse of so many great geological eras except a comparatively thin accumulation of ferruginous mud!

It might be said that the Upper Punjab formations are all excessively subject to lateral change, and that scarcely one formation or group is

* At one place north of Kálábágh the salt of the Loon (Lún) nallah belonging to the Salt Range series is found within about eighteen miles of that belonging to this district at Nundrukkí.

constantly present along the whole of the Salt Range itself; the salt series at its base being one of the most constant, and therefore that the absence of many divisions of the rocks here would be no uncommon occurrence, but then it is known that only ten or fifteen miles southward of the Kohát salt tract palæozoic* and mesozoic rocks were deposited, carboniferous, jurassic, and cretaceous groups occurring in and near Chichálí pass in the Soor (Súr) ghar mountains close to the Sheen (Shín) ghar range, while one or both of the latter formations may be found among the mountains just to the north and north-west of Kohát at a distance of twenty miles from the salt region. Thus, unless the salt series of this district formed dry ground, a most extraordinary cessation of deposition which was going on around within some miles† must have taken place during the two great early and protracted periods of palæontological time. If it were dry ground however the existence of unconformity or any traces of ancient denudation are wanting to corroborate the fact, and of all known varieties of rocks, soft clays, gypsum, and soluble salt, seem to be among those least calculated to preserve their original surface of deposition, or to resist the action of atmospheric denudation during countless ages.

There being no signs of the removal of the ancient formations from above the salt, imagination fails to suggest by what barrier deposition could have been arrested during such a lengthened time, and it is therefore well nigh impossible to believe that this salt series can be in any degree contemporaneous with that of the Cis-Indus area.

* Carboniferous both sides of Chichálí pass. Fleming's report, cit. pages 261 and 461. The jurassic and cretaceous groups were seen here by the writer and identified by Dr. Waagen, who thought some of the lower beds might possibly be triassic. The carboniferous beds do not appear in the Pass section.

† Distances to which the former expansion of Jrd in north and south directions may be added.

A sacred saline spring giving off inflammable gas has also been heard of near or on Mr. Medlicott's Gumber fault near Juwala Mukí, a dozen miles or so westward of Kangra, also in the tertiary rocks.

This line of enquiry suggests one improbability after another, and when these are contrasted with the appearance of parallel sequence previously described, weight may be given to the consideration that one of the minerals forming a rocky band in the salt series, namely, gypsum, is of common occurrence in varying amounts among the early tertiary rocks of Northern and Western India; for instance, in Kutch,* at Linyán† in Sind, in the Subáthu ferruginous clays of the Simla country,‡ and along the northern side of the neighbouring Potwár plateau, extending up into the Murree hills,§ associated with red or variegated or greenish gray clays, as here. The inference from this is that some at least of the conditions by which certain of the results were produced here existed widely at the commencement of the tertiary epoch.

Besides this there are salt and petroleum springs in Burmah,|| which rise from presumably lower nummulitic rocks, and in the Nún or Lún river below Masurí a salt-spring also occurs in the tertiary series.¶

There is a strong brine spring issuing close to nummulitic limestone south of the Bakrála ridge at Kalrá north-west of Jhílám, and some weaker brine springs are reported in the Subáthu rocks of the Potwár plateau westward by north from Fatehjung, a considerable town near the petroleum wells of Ganda, some thirty miles west of Ráwál Pindí. An analogy between the sources of the salt of these tertiary and lower tertiary brine springs, and the salt of the Kohát Frontier region, may not appear far fetched when it is remembered how great is the extension of the nummulitic formation stretching on both sides of the Himáláyá from Burmah, through the Punjab, Afghánistán, Persia, Arabia, Egypt

* Memoirs, Geological Survey, Vol. IX, pt. 1, pp. 76, 90, &c.

† Ditto ditto, Vol. VI, p. 4.

‡ Ditto ditto, Vol. III, pt. 2, p. 177.

§ Records ditto, Vol. VI, 1873, p. 61.

|| Ditto ditto, Vol. VI, 1873, p. 67.

¶ Memoirs ditto, Vol. III, pt. 2, p. 177.

and along Southern Europe to the Pyrenees (in fact from Spain to China).*

In a formation so extensive, the recognition of which is traceable to the original similarity of certain (eocene) conditions, others also may well have occurred at wide lateral intervals, and those resulting in saline accumulations at this period are known to have done so in Europe and elsewhere.

It is certainly peculiar that in such close proximity here there should be two salt series of great thickness and extent, one of not younger than silurian age, and the other associated with nummulitic rocks, a fact which is of itself suggestive of strange conditions from earliest times having affected the region of the Upper Punjab, if it does not point to an ancient local and recurring source for the mineral.

The differences pointed out in the character of the salt itself, contrasted with that of the Salt Range, together with the diversity marking the whole geological section in the two regions, and the difficulty of finding an adequate explanation of the absence here of the great overlying Salt Range series, seems sufficient to warrant the conclusion that the rock-salt deposits of these two regions are of entirely separate age: while the details given and to follow indicate that the Kohát salt, if not, as appears likely, absolutely eocene, is, at any rate, not much older than the base of the nummulitic formation.

Modern theory of the formation of rock-salt.†—This is hardly the place to dwell at length on the state of geological knowledge regarding the origin of rock-salt masses, which, it appears, may occur in any formation, from the silurian, as in the Alleghany Mountains (Abingdon), Washington Co., Virginia, United States of America,‡ and in the Punjab,

* Fisher, Geological Magazine, Vol. X, p. 257.

† The subjects referred to in this section have frequently been discussed with Dr. Warth.

‡ Karsten's work quoted; also Dana's Mineralogy.

up to the tertiary, as in Europe (among the eocene rocks of the Pyrenees, and in Germany), as well as here, or above the eocene, as in Persia.*

From the way in which the subject is treated by Lyell, Jukes, Page, and other authors, it would appear that modern writers on geology incline to the belief that rock-salt has been accumulated by the evaporation of salt-water or the sea, under favourable circumstances, some of which may be taken to mean such as would enable apparently natural consequences of the evaporation to become reversed—the deposition of sulphate of lime (gypsum), which would ordinarily be thrown down first, being delayed till precipitation of the salt was accomplished—because usually when the two rocks are present (as in this district) the gypsum seen overlies the salt.

The unascertained influence of high temperature in producing this result is alluded to by Page, who says that from the connexion of many of these deposits with axes of elevation, it is more than probable igneous action had to do with their formation. It is known that salt (chloride of sodium) is very slightly more soluble in hot water than in cold, but heat has a strong effect on the solubility of gypsum, which forms an exception in being so much less soluble in hot than in cold water, that by heating a cold aqueous solution containing the mineral the latter will become insoluble and be precipitated. Thus, heat which would not retard the solubility of salt, nor affect it much in either way, may possibly have come into operation to hasten the deposition of the gypsum and so influence its distribution.

The great difficulty as to superposition of this latter rock might be lessened if it could be supposed that mechanical destruction and recomposition of previously existing gypsum overlaid by salt had taken place. Most cases of such recomposition in stratified deposits tend to transfer the newer rock on removal to situations beneath the materials derived from the older, this being later acted upon. Instances of the

* Loftus, in *Quar. Jour.*, Geol. Soc., Lond., Vol. XI, p. 334, &c. Blanford, *ibid*, Vol. XXIX, p. 501.

kind will be suggested by the action of rivers, by coasts and hollows which are being silted up, without the necessity of seismic disturbance, or, comparatively speaking, much difference of level. Still it appears strange if this were the case that the original order should not be more frequently met with in connexion with these deposits; and, further, if the prevalent arrangement were not the original one, it would be expected that in such great natural salt-pans as the grand Runn of Kutch, thin layers of gypsum would be found underlying the incrustation of salt, no instance of which has come to notice.

The effects of pressure and heat combined have been appealed to (Phillips) in order to account for possible conditions under which the deposition as found could have taken place; and these are indicated among other causes (such as chemical and molecular change, percolation, and magnetic currents) for metamorphism of strata as deposited into rocks like these, reasoning based on these suggestions being thought likely to lead to a solution of the problem (Page). Besides solar evaporation, gaseous emanations of solfataras and mineral springs are hinted at by Lyell as capable of connexion with these deposits; but all authorities seem united in the opinion that we require further knowledge of the chemical changes in seas where volcanic agency is in progress, of the ancient hydrography of salt regions, the chemistry and physical geography of the ocean, before "results apparently beyond the production of any known operations in nature" can be satisfactorily accounted for.

With reference to heat as one of the conditions among those just mentioned, it should be noticed that the presence of small quantities of petroleum or other hydrocarbon in the Kohât salt, if coeval, may be evidence against any temperature high enough to have driven this off.

In conformity with the apparently received solar evaporation theory, the salt or sea-water may have occupied a large evaporating basin over much of the bottom of which it had laid down a deposit of gypsum. The proportion of the latter in sea-water is greatly smaller than that of

salt, being only between $\frac{1}{2}$ and 1 per cent., but the point of saturation with sulphate of lime being so much more quickly reached, gypsum might become widely spread, while the water would not part with the salt till continued evaporation had caused saturation thereby and greatly contracted its area, (in the case of sea-water the volume of the salt only representing $\frac{1}{30}$ th of that of the water by which it would be deposited), the thick accumulations of this mineral indicating deeper pools left in the basin as it dried up. Thus the gypsum might occupy a much larger original area than the salt, and this area rising round the saline pools might contribute largely to the formation of a gypseous deposit capable of being mechanically removed to overlie the salt in the manner now seen.

Dr. Warth has suggested that deep brine pools such as these might be overflowed by more slightly saline or non-saline water bearing gypsum in solution or clay in suspension, which from its less specific gravity would not mix with the heavy brine below until it had reached the same point of saturation, and that in this way layers of clay or of gypsum could be deposited upon, or alternating with, bands of salt, the crystallization of which would be permanently arrested by larger accessions of fresher water.

Even supposing the formation of rock-salt possible as above supposed, the very magnitude of the enormous accumulations of exceptionally pure salt-rock in this Trans-Indus district still involves much obscurity as to their source, partly perhaps from the slightness of present knowledge as to what is taking place in the depths of many existing seas, whose waters must evaporate and be replenished by rain, and also by rivers bearing mineral matter in solution from the land; while in some oceans at least the currents are shown by recent research to be unfavourable to the separation of saturated brine or the formation of rock-salt.*

* Dr. Carpenter's lectures on ocean temperatures and oceanic circulation—*Prog., Roy. Soc., 1872, Vol. XX, 535, &c., on the 'Shearwater' Scientific Researches—to Royal Institution, 1874, March 20. 'The temperature of the Atlantic'.*

This may nevertheless be going on in favourable situations, as is said to be the case in a land-locked arm of the Caspian;* or, as has been suggested with regard to the Red Sea, notwithstanding that deep ocean soundings in recent years have not borne witness to the fact.

In discussing the circumstances of the salt region under notice with Dr. Warth, it appeared that if a column of sea-water may deposit $\frac{1}{50}$ th of its volume of solid salt† it may be roughly calculated that to produce the two square miles of salt taken at $\frac{1}{3}$ th mile thick at Bahádur Khél, a volume of sea water of the same depth and 100 square miles in area (equal to twenty cubic miles) would be required, and this should probably be evaporated to half its original bulk before deposition of salt would commence.

If the whole of the salt deposits be considered to represent a series of brine pools formed by the slow desiccation of a once continuous sea, the area within which they occur being one of about 1,000 square miles, and the salt presumably present over more than $\frac{1}{3}$ th of this area, or 200 square miles, this sea may have had a depth equal to the unknown thickness of the salt deposits in most of the districts, and a superficial extent of 1,000 or 2,000 square miles according as it may have been deep or shallow, while if the rock salt be, or was once, continuous from one exposure to another over the whole area of 1,000 square miles, the extent of the depositing sea may have been from 50,000 to 100,000 square miles.

* At Kara Bugaz (?) (i. e., The Black Gulf), eastern side of the Caspian. The accumulation of the salt in this case may be gradually increasing, but it is by no means clear, so far as can be learned, that the sources of the salt supply are not traceable to the rock-salt stated by Karsten to occur extensively on the eastern borders of the Caspian rather than merely to its own waters.

† Bischof (quoted by Jukes in his Manual, p. 137,) gives saline matter in sea-water as 3.527 per cent., of which 75.786 is chloride of sodium. Taking sea-water to contain sixteen times as much salt as gypsum (same authority), it is curious to note the similarity of this ratio to that between the calculated thickness of the salt and gypsum in the Bahádur Khél exposure.

Anything worthy of the name of an inland sea or large lake would cover the whole of the salt-bearing country, as far as extent goes, and as the gypsum extends much beyond the salt region, while all the rocks of the district may once have had an expansion one-third greater in a north and south direction, it is probable that the saline water would have occupied or exceeded the largest area named.

This rough estimate will serve to show that, according to existing natural conditions, there is sufficient salt in a rocky form in this district to have impregnated all the waters of a considerable sized inland lake or sea. The mode of its collection into the form of solid strata of large thickness and greater or less horizontal extent, or the conditions under which the water would have disappeared by evaporation, conformably with what appears to be the most generally adopted theory, can only be surmised.

In the last paragraphs sea-water has been used to illustrate the probable formation of the salt, its composition being better known than that of the waters of many inland lakes or seas, which might give different results, but from a passage in Dr. T. Sterry Hunt's lecture on the chemistry of the primeval earth (Geological Magazine, Vol. IV, p. 364), he would seem to believe that "there has been a slow progressive change in the constitution of the ocean," so that the conditions may not now remain the same as they were when the salt was deposited.

Assuming these to have been at least similar to some extent, what special causes there may have been in operation to facilitate the formation of the rock-salt there is little or nothing to suggest. In this connexion it may be observed that the circumstances of deposition generally in the Upper Punjab seem from very early palaeontological times to have been subjected to strange peculiarities of lateral limitation. The thinning out of whole formations may only mark absence of material to be deposited; in the case of sedimentary rocks, but in those of chemical origin, the depositing seas would themselves appear to have been limited or divided by land. Together with the

frequent repetition of discontinuity, there is from the lowest to the highest groups in some regions such an absence of unconformity that through the long list of periods down to tertiary times results of any violent local disturbances are unknown, these only being referable to causes connected with Himáláyan elevation and dating from the eocene age.*

In such a vast succession of comparative tranquillity (if the absence of older rocks than nummulitic could be explained), time might have been adequate and ample for the accumulations of a thickness of salt rivalling that of all the known palæozoic fossiliferous accumulations of the Salt Range and far exceeding in depth many of its separate groups, some of which might even be supposed represented in time by part of this great salt series; were it not that even after making allowance for formerly greater superficial expansion of the country, there are still no reasonable grounds for the belief in such a permanent 'Swatch of no ground,' and of no deposits existing between the points where mesozoic or more ancient deposition is known to have been taking place.

If we turn to the known natural salt pans of the present day for an illustration of the method by which such enormous deposits of rock-salt as these were accumulated, it may be strongly doubted whether the whole world affords anything approaching a parallel case likely to produce a similar result. The Bunn of Kutch is a favourite example of the natural formation of salt from sea-water on a large scale, under conditions of intermittent floodings by saline water, yet the salt formed there by evaporation is only a few inches thick and not sufficient to cover the whole of its surface, while the formation (even if accompanied to some extent by re-solution) has been going on for an indefinitely vast period, but little interfered with by one of the greatest earthquakes of the present country.

* The occurrence of boulders of foreign rocks is not here contemplated. Although these occur in some of the oldest groups, they are no evidence of local disturbance, but rather of tranquillity enabling them to subside.

The Sambur Lake, another Indian example, fails also to afford a parallel to the magnitude of the salts in the case before us, and of others so little can be asserted to the contrary, that it may safely be presumed the salt-producing lacustrine or lagoon conditions of the present time are so unequal in comparison as to have no weight in supporting the idea that the causation of the frontier salt deposits was at all the same.

The structural indications of the manner of accumulation of these salt beds are few and may be briefly mentioned. The frequently perfect stratification of the salt plainly shows repeated or periodic deposition and cessation, while the occurrence of the numerous cases of oblique lamination exactly as in other rocks points to the existence of currents in the depositing water. The freedom of much of the salt from visible impurities or foreign substances testifies to the clearness of the fluid, but it would be unsafe to assert that this water was itself the only source whence the mineral was derived.

The impregnation of some of the salt with bitumen or petroleum is the only remote indication of anything organic associated with it, and the origin of this is entirely obscure. Salt-forming regions are usually lifeless; no place could well be more so than the Runn of Kutch; the description of the Dead Sea will be familiar, and at the Abyssinian salt regions, Karsten alludes to the absence of living things as enhancing the barren desolation of the dreary scene.

GYPSUM.

As a rock.—As another of the rocks of the district, the gypsum group holds an important position from the large area it occupies. Closely associated with the gypsum itself are certain thick zones of greenish, sometimes smoothly stratified, clay, often containing translucent crystalline plates or fragments of selenite which glisten on its weathered slopes; these clays have only been found to enclose impressions of small fragments of grass-like plants.

Occurring with the clays, and in places as if below the main gypsum, or both below and above it, are bands of limestone sometimes hard and compact, sometimes flaggy and transversely crossed by a fibrous crystalline structure, which more or less perfectly takes the well-known form of 'cone-in-cone.'^{*}

Both the gypsum and associated clay have received from the natives distinguishing names, the gypsum being as well known by the name *Speenki* as the salt by that of *Malga* (Pushtú), and the clays being called *Sheenkoura*.

Character and solubility.—The gypsum, as indicated by its Pushtú name, is very generally of a white color, showing itself plainly even on dark days at long distances among the hills, but it sometimes has a grayish hue,[†] more rarely variegated with deep red from decomposition of iron, and it often in its lower part passes into shaly beds, quite black, smelling strongly of petroleum; its texture varies from subcompact to more crystalline varieties.

^{*} Close outside the district.

[†] The Potwar gypsum is also white or gray, and associated with clays very similar to *Sheenkoura*.

WYNN: TRANS-INDUS SALT REGION, KOWAT DISTRICT.

Two specimens of the dark-coloured beds, associated with the gypsum, and smelling strongly of petroleum, examined at the Laboratory of the Geological Survey by Mr. Tween, gave the following results:—

			No. 1	No. 2
			Dark bituminous gypsum bed from Jatta Salt Quarries.	Dark bituminous shale with traces of gypsum Algal, between Mandu- kai and Spina.
Loss on heating	..	...	18.6	5.6
Soluble	...	...	35.8	80.2
Insoluble	...	...	45.6	5.2
			100	100

The greater part of the soluble matter in No. 2 consists of carbonate of lime.

Impurities.—As a rule, the gypsum is pure and homogeneous, the only foreign matter observable in hand specimens being some gray clay, crystals of iron pyrites, crystals of quartz, dolomite, or anhydrite in a few places, and the bituminous ingredients of the black portions.

The anhydrite just mentioned is rare, occurring in the form of very small, but beautifully clear crystals, imbedded in the lowest stratum of the gypsum just above the main mass of the salt at Saya Malgeen (Səya Məlgin).

Alum shale.—Associated with the gypsum in the eastern side of the district are one or more bands of black alum shale, so charged with pyrites as to have formerly induced their being worked for sulphur, which occurs native in small quantities, the result, apparently, of chemical reaction going on at the places where the shale occurs, and from which sulphurous gases emanate. The rock, too, is frequently coated with alum to such a degree as to affect one's skin in handling it.*

* Dr. Verchere suggests that alum shale in a neighbouring district is a product of the metamorphism of lignite, but does not describe the process (paper previously quoted, p. 27)

The broken and disturbed character of the series renders it difficult to fix the place of these alum shales with certainty or narrowly, but they probably form a band not far above the lowest layers of the gypsum. In the country lying southward and south-eastward of this district two zones of alum shales occur, one near the base of the nummulitic rocks, the other in the jurassic series; these here may be the representatives of the newest of those in the nummulitic rocks, for though the associated beds differ, the relative place beneath the mass of the nummulitic limestone is approximately the same.

Stratification.—The stratification of the gypsum is not uniformly evident; in some places the beds appear to be thick and massive, or the bedding laminæ are indistinct; in others it becomes thinly divided or flaggy, showing alternations of gray and whiter colour. The lamination is rarely parallel; more frequently it assumes complex folds, sometimes on as small a scale as may be observed in the contorted foliation of gneiss or other crystalline rock. The alternation of the gypsum with the gray clays is in places very distinct, in others most obscure, and towards the top of the main gypseous band, this frequently passes by alternation of thin layers into the red clay zone which follows. Where the soft clay has been washed from between these upper gypsum layers, as well as occasionally in other parts where the stratification is clear, distinct current or 'ripple' marks have been observed on the surfaces of the beds, indicating their having been accumulated in shallow water.

Fossils.—No organisms whatever have been found in the gypsum, and none in the associated gray clays, except the obscure grass-like fragments already mentioned, but in a limestone band near the top of the gypseous group associated with gray clays, some small and fragmentary shell impressions were detected. One seemed to be a fragment of an oyster, the others might have been anything.

Wasting.—The solubility of the gypsum by rain is plainly shown by the way in which its surface is frequently deeply fretted into minia-

ture models of hill ranges, with serrated knife-edge ridges and deeply-gullied sides, or where it is (as is not uncommon) traversed by rectangular veins of greater hardness, the interspaces between which are often eroded into perfectly flat-bottomed hollows like little salt-pans; the surrounding lips of these sometimes have no opening or depression to enable the water to drain off, so that the dissolved mineral from within can only have been removed by the wind or by overflow.

This system of rain furrows, always more or less upon the same plan, may be frequently found upon surfaces of homogeneous limestone, more frequently upon gypsum, and most largely developed upon the exposed exterior of the rock-salt.

Another result of the solubility of the gypsum is its apparently frequent recomposition or rearrangement into a rock somewhat resembling calcareous tufa. This form of the mineral or rock occupies, as a covering, much of the gypseous ground, conforming rudely to its surface even in deeply cut ravines. Such masses, on being searched, may be found to contain some decayed fragments of limestone in which are nummulites as well as pieces of other local rocks, and in the paste small crystals of dolomite and bipyramidal clear quartz may be met with. Unlike calcareous tufa, stems, leaves of plants, &c., do not appear to have been preserved by incrustation or replacement.

The gypsum not limited to one zone.—Though prevalent in great and more or less continuous masses, the gypsum cannot be said to form an unbroken sheet, its apparent discontinuity being perhaps due to dislocation or denudation, or both. Nor is it limited either above or below by any arbitrary boundary. Thus, in the Malgeen Séya (Málgín Séya) hills a layer of salt was seen to separate a mass of dark gypsum from the rest above; in other parts of the eastern side of the district layers of limestone, or of limestone and clay, were observed near the top of the main gypsum mass; beneath a less strongly developed bed of the latter, and in about the centre of the salt region, thick bands of gypsum

occur among the basal beds of the nummulitic series. They are not, however, constant, and one was traced till it thinned out between the adjacent beds of limestone.

Thickness.—The disturbed state of the ground places much difficulty in the way of estimating the thickness of what we may call the gypseous series. In *one* section at Bahádur Khél, the gypsum has no greater thickness than 32 to 40 feet, and the gray clays are there but poorly represented. In other parts of the district one is perhaps inclined to overestimate its depth from the manner of its exposure, presence of superficial gypsum, &c., but in some cases it certainly seems to have a thickness of, or approaching to, 200 feet, while with the clays, the whole may average more than 300 feet.

Conditions of formation.—The circumstances accompanying the deposition of this series as indicated by the rocks must have differed considerably from those which obtained during the formation of the underlying salt. The clearer waters were now liable to influx of clay or mud, and again probably still and clear while the gypsum was being deposited, becoming occasionally shallow and subject to currents which left their traces, as they do now, in the form of ripple marks on sandy or muddy bottoms.

The amount of gypsum which water may dissolve is very small, not being more than 2·5 of gypsum in 1,000 parts of water, and its accumulation from aqueous solution in the present case would point to long intervals during which earthy impurities were not present in the water in any quantity, alternating in places with an opposite state of things when mud or clay was greatly in excess. The deposition of the gypsum from solution would doubtless have been hastened by accession of heat, if this could be shown to have taken place, but whence it might have been derived there is nothing to prove. The water may have been at times so shallow as to have its temperature raised by the heat of the sun, or thermal gypseous springs may have been in operation (as shown to have been the case in the Spiti valley by

Mr. Mallet),* sending forth volumes of warm water which could have floated over a denser saline liquid below (as previously observed), or it may be possible that the 'mother liquor,' after depositing the salt, may have retained a quantity of chloride of calcium, the accession to which of water impregnated with sulphate of magnesia or soda would have produced sulphate of lime, *i. e.*, gypsum.† As with respect to the salt, so in the case of the gypsum, the presence of much heat, at least since the rock became impregnated with petroleum or bitumen, does not appear probable; on the other hand, the small quantity now present may be but the residue of a larger supply already driven off. Hot springs and so-called hot springs are not unknown in the Punjab now, and if these were more frequent or more voluminous in bye-gone ages, their existence might not be incompatible with the fact that latent forces of disturbance still show themselves in the frequent earthquakes, one of which was distinctly felt at Láchí during the examination of the district.

All such views, however, infringe largely upon the regions of conjecture, for which there is generally ample room when facts are scarce.

* On the gypsum of Spiti, Mem. Geol. Surv., Ind., Vol. V, p. 151. Hot springs are also supposed to have aided in forming the gypsum of the Salt Range by Dr. Verchere,—paper previously quoted.

† Dr. Warth.

RED CLAY ZONE.

Generally present.—Overlying the gypsum there is very generally present a thick zone of deep red clay, the presence of which is often indicated by the colour of the talus at the base of the nummulitic limestone outcrops. There are, however, situations where in an exceedingly broken, disturbed, and often concealed country, this red zone does not always appear next above the gypsum, giving place to sundry gray clays, shales, or brownish sandstones at some height in which a less developed red clay band, believed to be the representative of this, occurs. Where these gray clays and sandstones are absent, as is the case over most of the district, the red zone, or its débris, is always to be found in any consecutive section of the rocks occupying its proper place.

It seldom shows its stratification well, but under favourable circumstances, bands of slightly different tint mark the bedding, or there are alternations of more sandy nature, sometimes becoming flaggy and variegated by green spots.

Similarity to other red bands in the Punjab.—Where this flaggy structure prevails the group so much resembles a red zone, believed to be of triassic age in the Eastern Salt Range, that it has been searched for the pseudomorphic crystals of salt so common there, but without success, and there is no other similarity to the Salt Range band, the rocks above and below which are always absent here. Some resemblance might be traced between the brownish sandstone and gray clay series, in some places overlying the red band here, and the olive series above the Salt Range red zone, but the comparison would not hold, for the olive series contains a few fossils, believed to be cretaceous, while the brownish sandstone and gray clays of this country are nummulitic.

But there is another set of red clays in the Upper Punjab to which this is also very similar. It is traceable at intervals wherever the Subáthu zone is found closely associated with the nummulitic limestones. The colour is much the same, and both contain sandstone or sandy alternation, differing, however, greatly in development in the

Cis- and Trans-Indus regions. The association of both of these red bands with nummulitic limestone favours the supposition of their being both of nummulitic age, though it is not sufficient to warrant the assertion that they are on exactly the same horizon.

Bone and other fossiliferous beds.—Near the top of this red clay group a single or double layer of harder rocks may frequently be observed. These are sometimes coarse purple sandstones, each seldom more than a couple or three feet thick; sometimes they are thinner, and concretionary or pisolitic hæmatitic bands, while in some localities they become thicker and conglomeratic, containing also small fragments of bones, unfortunately not likely to be of use in fixing their age. At a locality far distant from where the bones occur, some layers with *Nummulites* were also observed in these red beds not much below their junction with the overlying limestone.

These few traces of fossils are among the oldest and earliest traces of existence in the whole of the Salt Region, the few fragments in a limestone band at the top of the gypsaceous series being older, but neither being in a state of preservation likely to convey any information as to age, and in no other part of the red zone has any better fossil evidence been found.

Representatives, east and west.—From a passage in Dr. Verchère's paper previously alluded to,* it might be surmised that the rarely hæmatitic layers of this group are developed more largely westward in the country of the Wazírí, furnishing the Wazírí iron of commerce in these parts. In the Salt Range to the east, the only representative which can be suggested for the group is a band of red and white variegated hæmatitic clay of inconsiderable thickness, which occurs just beneath the nummulitic limestone of the range.

Thickness.—The thickness of this red clay zone varies somewhat, being seldom small, and sometimes measuring over 300 feet or even nearer to 400 feet. Two hundred and fifty feet, however, may be an

* Jour., As. Soc., Bengal, 1867, p. 20.

approximate average, but it has in places been found to measure even less than 20 feet.

Conditions.—With the deposition of this red zone things must have changed again, and locally so much that its regular succession was much obscured. The water in which it was deposited was charged no doubt with ferruginous matter, whence the colour it now assumes. The lowest layers alternate clearly with the gypsum for a short space (just a few feet); a certain amount of variety is indicated by the local presence of sandy materials, and the upper layers containing nummulitic bands; the whole group would seem to link the nummulitic and gypseous groups into one series.

Minerals.—On the horizon of the harder bands near the top of the clays, a sandy bituminous layer was observed in a stream gorge west of Muzdukkai hill. It varied from 1 to 3 feet in thickness, and seemed so saturated with mineral-oil as to increase its weight, yet this did not seem to exude. This, the pisolitic hæmatite layer, some narrow gypseous strings, and thin veins of sulphate of baryta, with some small concretions stained with green carbonate of copper, were the only minerals observed in the group.

NUMMULITIC SERIES.

Formation inconstant in the Punjab.—The nummulitic rocks of this district belonging to one of the groups of the Upper Punjab most liable to local changes—changes which are, nevertheless, insufficient to affect the recognition of the formation in different parts of the country, the formation may be said to present itself under three more or less separate aspects, namely, those of the Salt Range type, the Subáthu type, and the hill nummulitic type.

Here the two former of these types seem to be united so that the local groups may be looked upon as exhibiting an unusually extensive development of the Subáthu character blended with some of the features characteristic of the Salt Range nummulitic zone.

Local inconstancy.—As the general features of the nummulitic rocks of the country are versatile, so, even within the limits of this salt-bearing region, the sections across it vary in different places, from the entire absence of this group by thinning out, to its enhanced thickness by including beds not usually present. Where thinning out of the limestones takes place, the upper portions are always the first to disappear ; and the chief additions to the whole group are a mass of shales and sometimes of light coloured sandstones, which locally come in below the main limestone zone.

General succession.—The inversions of the adjacent strata are most prominently marked by the occurrence of these limestone beds, which, as it were, form a key to the complicated stratigraphy of the hills, being most extensively distributed, while the clays or soft shales and sandstones are collected into a group by themselves at the base of the series, rather than distributed by alternation through it, though occasional bands of shale do occur also in the latter way. The following may be given as a diagrammatic table of all that is certain to belong to the nummulitic limestone group in this district, there being, however, reason to suppose that this eocene series may include all the rocks below the limestone

itself. It does not follow that the whole of the rocks in the following list should be present at any one place :—

Nummulitic series.

8. Variegated yellowish, light-gray yellowish and pinkish, or gray or whitish limestone or marble, lumpy and marly beds below with *Nummulites*, *Alveolina* throughout.
7. Gray limestone with *Alveolina*.
6. Gray limestone, rather darker, containing small *Nummulites*.
5. Thick and thin-bedded regular limestone, few fossils, some of the beds semi-collitic.
4. Earthy gray limestone and greenish shale with *Nummulites*.
3. Dark cherty limestone with few fossils, a few feet only.
2. Gray limestones and gray or greenish clays, thin-bedded layers, *alveolina* bands occasionally, or layers with *Nummulites*. On or about this horizon, brownish sparkling sandstones and gray or greenish-olive clays, with bands of red or purple clay, are locally present in north-westerly sections; the sandstones being in places conglomeratic.
1. Greenish clays sometimes gypseous or containing plates of selenite below, sometimes having calcareous *nummulitic* layers.

Where the groups 1 and 2 of this list are present, the red zone so prominent elsewhere loses its character and place as next overlying the gypseous series, pale brownish sandstones and greenish clays taking an intermediate position between the gypsum and the now sub-divided and thinner representative of the deep red or purple clay zone. The bands most retaining the general appearance of the latter are usually those nearest to the stronger limestones above, and these red bands are certainly interposed between or intercalated among beds containing *Nummulites*, thus giving another clue to the fact of the red zone itself and the gypsum into which it passes below by sudden alternation—all belonging to one early eocene period.

In order to show the difference between the ordinary junctions of the red clay zone and nummulitic limestone and the obscure passage downwards from the latter where the sandy and shaly lower nummulitic beds are present, the sections south-west of Amon Kót and Shárki.

(fig. 17) and (fig. 18), may be compared with those on the Kúrshru Alguḍ near Bahádur Khól, (fig. 36), and near Gúrúza, (fig. 42.)

Sandstone bands similar to tertiary sandstones.—Apparently about the place of No. 7 in the foregoing list, there are sometimes a few beds of purple sandstone and clay present, very much resembling those of the succeeding tertiary sandstone group. In several instances such bands, apparently within the limestone group, have been found to belong to the series above misplaced by dislocation, or brought in by both curvature and faulting, but in other cases, from the apparent regularity with which these bands seem to be included, it would be unsafe to assume that they are never really intercalated with the limestones.

Concealment by débris.—If the nummulitic limestone affords a key to the structure of the country, on the other hand, the quantity of hard débris which it forms overshooting the slopes of the hills mostly on the outcrop side, adds greatly to the difficulty of seeing the complete succession of the rocks, many miles of hill side being covered, and the rock beneath almost entirely concealed by this débris, from the limestone of the ridge to the foot of the declivity, and frequently in situations where only a few projections of gypsum serve to indicate the interest of sections which the ground might otherwise afford.

Varieties in succession.—The lower rocks are gray shales or clays with occasional calcareous bands. They take a greenish olive colour where weathered, and are not unfrequently gypseous, being then undistinguishable from the ‘*Sheenkoura*’ beds of the gypsum series below. In these clays or shales fossils are often rare for a depth of very many feet, but become suddenly abundant in thin or flaggy layers of limestone largely made up of *Nummulites*. Thicker beds of limestone occur irregularly higher up containing numerous fragments of oyster-like shells and sometimes a few corals.

At about this position the greater portion of the shales of some localities underlie strong brown sandstones of soft texture and light colour, in parts conglomeratic and enclosing nummulitic pebbles as well

as nummulites in the paste, thus showing that even at an early date the rocks of the group were irregularly distributed, and that limestones were suffering degradation, while other beds of the same period were being deposited, but at what distance from the former we have no evidence to prove.*

These sandstone beds have rather a local distribution, and appear to be developed with, or as a part of, the clays or shales just mentioned.

So situated as to overlie the clays, sandstones, and limestones described is a zone of very dark-coloured limestone with rugged bands of white chert. Fossils are rare in the band, except some few sections of large, spiral shells and even less frequently a discoid gastropod having somewhat the form of *Planorbis*.

Above these are gray, earthy, nummulitic limestones with some bands of greenish shale, followed by thick and thin-bedded parallel limestone

* The presence of such pebbles as these is always rather difficult to account for where no absolute unconformity is known to occur. At first sight they might seem conclusive evidence of the existence of an older limestone, its erosion, transport of its fragments, and their deposition elsewhere. Limestones, especially these with nummulites, have been often considered pelagic, the nummulites being supposed deep sea organisms, but that the waters in which nummulites lived need not in all cases have been so very deep may be considered proved by the manner of occurrence of the nummulitic beds—sometimes sandstones—of the Subáthu group, exterior to the hill limestones lying northward from Ráwál Pindi.

If some of the limestones could be supposed capable of consolidation near coasts becoming thus liable to destruction by wave action the mystery might be solved, for I have seen a sandy calcareous rock on the Indian shore of the Arabian Sea becoming consolidated between high and low watermark, the recent shells in which were converted into white limestone. Fragments of this rock, broken or worn down by the surf, would be included in the sandy shore deposits containing the same shells, and yet be no evidence of unconformity which, strictly speaking, requires the erosion of a land surface. Nor does it seem unlikely that light bodies like *nummulites* might be removed, cast up by waves and enclosed in a rock so formed, without bearing any prominent or visible traces of having been rolled, in which case they would appear to have been enclosed where they had lived. An old shore line, if it could be pointed out in these deposits, would complete the analogy. This would of course indicate unconformity, but not among the shore beds themselves.

layers having few fossils. These are again overlaid by lumpy, marly, light-coloured bands full of *Nummulites*, *Bivalves*, a few *Gastropods*, some *Echinoids*, and a general assemblage of ill-preserved nummulitic fossils, the whole being succeeded by hard pale-gray or variegated compact *Alveolina* marble, often of a dull, yellowish colour, and generally forming the highest portion of the nummulitic limestone group. Perhaps the most constantly present beds of the formation are the hard *Alveolina* bands, but there are others of the more lumpy and earthy-looking light-coloured limestone, apparently lower in the series, also very generally present; they contain a characteristic *Gryphea*-shaped fossil. The *Nummulites* are of various common kinds, generally present in the Upper Punjab eocene; many of these are already described; but no thorough examination of the nummulitic fossils has as yet been made. The size of the *Nummulites* varies from extreme minuteness to nearly an inch in diameter. The *Alveolina* also vary in size from that of a grain of rice to three or four times the same proportions.

Characteristics.—The lumpy fossiliferous bands, the generally light colour of the rocks, their containing large sized *Bivalves* in some places and less commonly large *Gastropoda*, the occasional occurrence of some carbonaceous layers near the base, as well as the variable character of the whole group, are all points which tend to link the nummulitic group of this region with that of the Salt Range.

On the other hand, the presence of the greenish weathering clays or shales, the fine earthy or somewhat lithographic appearance of some of the beds, their pale colour, and their containing the large *Rotalina* so frequent in the Subáthu limestone and clay series, unite the formation, as exposed here, with that of the Subáthu series from the Indus to Murree, if not further eastwards.

Conditions.—The circumstances of deposition must with the advent of this series have undergone still further change, the muddy ferruginous waters so generally distributed becoming locally charged first with

mud of less ferruginous kind or sand, and occasionally pebbles, afterwards clear, either precipitating carbonate of lime, or crowded with lime producing animal organisms, or both causes for the calcareous accumulations may have existed. The presence of *Nummulites* has been usually taken to indicate deep seas; but from several features of the Subáthu nummulitic beds of the Upper Punjab, there may be reasons for doubting whether this were always a necessity of their existence.

Thickness.—The formation in this district varies greatly in thickness, the latter being of course very much increased if the gypsum and salt below be included. The uppermost calcareous portion is often a narrow band of hard limestone, showing extensively where inclined at a considerable angle, but where nearly vertical and crossed by ravines, the thickness is always found to be less than the display in the former situations would suggest. In many places the lower earthy part of the group is absent, unless represented in the *Sheenkoura* of the gypseous series, and for considerable distances the whole of the limestones have disappeared, leaving barely a few thin nodular, calcareous streaks to mark the separation between the red clay zone and the tertiary sandstones and clays overlying the nummulitic limestone group.

Where the red zone is present, as over most of the district, the lower limits of the limestone may generally be plainly seen, and the passage to the nummulitic clay shale and limestone can occasionally be closely examined, but the upper limits of the group are not always so clearly exposed. A rugged cliff line often occurs along the upper boundary owing to the sudden change in the texture of the rocks, and it is rarely, except in the clean cut sections of streams, that the junction between the limestones and sandstones can be inspected. Here the question of conformity or unconformity between the groups recurs to the observer as often as the contact is seen, the facts bearing upon which will be shortly alluded to in the description of the succeeding group.

Minerals.—The minerals of the nummulitic formation are few: some of the beds have a dolomitic appearance, and in some of the lowest

of the limestone portion of the strata nests of radiating spar were found, which gave the red Strontian flame before the blow-pipe, and probably consist of a mixture of this mineral with dolomite (or bitter spar). Some of the lower beds of the limestone also contain small nests of iron pyrites.

In some places just below the limestone part of the group are thin carbonaceous layers or pockets suggestive of the coaly bands very similarly situated in the Salt Range. They are, however, mere traces, and of no commercial value.

TERTIARY SANDSTONES, CLAYS, &C.

Three Sub-divisions.—Within this district the tertiary sandstone, clay and conglomerate series occupies by far the largest superficial area, and includes rocks which may be referred to each of the principal subdivisions of this great formation, as yet distinguished in the Upper Punjab, by the recognition of three groups or rather indefinite zones. These are as follow.

3. *Upper.*—Soft, bright-gray sandstones, and gray or orange clays with conglomerates largely made up of crystalline rocks often wasting into loose accumulations of smooth boulders. Bones may be occasionally met with.

2. *Middle.*—Gray and greenish sandstones and drab or reddish clays containing bones and fossil (exogenous?) timber in the sandstones. Reddish or red clays predominate below; and the beds pass downwards into—

1. *Lower.*—Slightly harder gray and purple or light-coloured sandstones frequently weathering, of a dark colour, and alternating with bright-red and purple clays. Calcareous and pseudo-conglomeratic bands occur frequently at intervals. The group contains *reptilian* bones below, with occasionally much (exogenous?) fossil timber, and close to the underlying nummulitic limestone, a thin reddish calcareous sandy layer has numbers of ill-preserved strongly ribbed *bivalve* shells.

Three zones also in the Simla Country.—Mr. Medlicott's researches in the Simla region of the outer Himáláyá have shown that there are also in that country on the flanks of the mountains and in the doons (dúns) below three main groups of these tertiary sandstones, conglomerates, and clays, but how far it may be possible to establish identity between the whole of these rocks as two sets of triple groups comprising lower, middle, and upper, or eocene, miocene, and pliocene, remains uncertain.

In that country each of the three divisions is separated from the next stage below by marked unconformity, while here no interruption to the most perfectly parallel superposition and sequence has been anywhere observed. The lower group, however, or Subáthú, would seem to be the same in both countries, its identity being based upon the recognition by Mr. Medlicott himself in the Murree hills and south of Káshmere of Subáthú characters* in the limestones, clays, and shales which are physically part of the 'Murree group' of the Cis-Indus, Upper Punjab. The upper part of this 'Murree group' he refers to the Dugshai type of the Subáthú rocks.*

These upper purple and gray 'Murree beds' (or Dugshai rocks) are identical in their general aspect and position with regard to the overlying series with those of the Trans-Indus group herein referred to the same placet† (see list of rocks, p. 24).

The highest group also possesses characters which go far to link it with the Sivalik series of the Simla region, and, further, a series of fossils derived from beds near the Salt Range, having in places all the appearance of the upper division of this country, were determined by the late Dr. Hugh Falconer as Sivalik.‡

For the intermediate beds, if it were thought advisable to have but two divisions instead of three, they might without impropriety be included with the upper rather than the lower group. They resemble more or less the descriptions given of the Nahun rocks as recently demarcated by Mr. Theobald (M.S.S.)

* Memoirs, Geological Survey, Vol. III, pp. 89 and 90. The valley containing "brown and variegated nummulitic clays." Trét and Sháh Durráh are in Ráwál Pindi, not Hazára district.

† See also Records, Geol. Surv., Ind., Vol. VI, 1873, p. 59 et seq.

‡ Paper on the Salt Range, by W. Theobald, Esq., Jour., As. Soc., Beng., No. 7, 1854. The late Dr. Falconer, however, made no distinction between the Sivalik and Nahun groups.

The whole series presents a great consecutive accumulation, the lower portion marked by greater hardness of the sandstones; their being, in certain zones, much veined with calcareous spar, and possessing a predominance of purple or red colours. Calcareous bands among the sandstones and clays, though seldom approaching to limestone in their nature, are not uncommon. As the series ascends, the red tint is limited to the clays and pseudo-conglomeratic concretionary beds, the sandstones having more of a bluish or greenish-gray colour, and still higher the clays become pink, drab, or orange, with occasional dark-gray layers. Here the sandstones become very soft, often of a shining whitish-gray colour within, or where crumbled down; and they contain strings of small pebbles. The latter increase in size and quantity till they become thick incoherent conglomerates or boulder beds sometimes cemented by carbonate of lime. The travelled boulders include a variety of igneous and schistose or crystalline rocks, believed to have been derived from the interior of the Himáláyan region. From their great hardness and smooth forms these pebbles and boulders have in many cases long outlived the beds in which they were laid down, and now thickly strew the ground, over large spaces, in which no boulder beds to furnish them could be found. The parent beds, however, may be seen *in situ* on both banks of the Indus near Makud and at the crags of Kaffir Kôt in the Wazírí country.*

The divisions between the groups are most indefinite, one passing into another gradually, yet approximate horizons may be so far identified in a general way that one can recognise to what part of the series any

* This place occurs in forbidden ground beyond the frontier. Not to lose a chance of acquiring information, a trusty messenger was requested to be sent by the Nawáb's people from Bahádúr Kháñ, for specimens of the rocks forming the crag. Accordingly nine men, fully armed, left British India for the cliffs, and returned with some of the well worn blocks of purple quartzite, yellowish quartz rock, &c., so common in the upper conglomerates, which, they declared, they had extracted from the cliff-faces. Seen with a field-glass from one of the nearest points within the "red line," a distance of about twelve miles, the crags presented nearly horizontal lines of stratification, which may have been marked by the contained blocks or their cavities.—See below.

large exposure is most likely to belong; beyond this sub-divisions could only be indicated by arbitrary lines, drawn from palæontological distinctions which have not yet been ascertained sufficiently to be applied to this district.

Thickness.—The thickness of the whole series must be very large, but owing to its disturbed, folded, and, in places, dislocated state, can only be roughly estimated at 5,500 to 8,000 feet for the part visible, the uppermost beds having been denuded away.

Fossils.—Fossils, though not unknown, cannot be said to abound in this tertiary sandstone series; plant remains and obscure fucoid-like markings are common in the purple and gray lower rocks in which an exogenous (?) fossil tree as much as 60 feet in length has been found among the lowest 'Murree' beds. Higher up vegetable impressions, often carbonised, also occur, and fossil timber* is likewise to be seen in the middle softer sandstones, but the chief fossils of the whole series are bones. Remains of large *crocodile* jaws, polished, striated, pointed, teeth, ribs and other large bones, tortoise plates, &c., are to be met with, but broken, scattered, and difficult to extract from the sandstones resting almost directly upon, the nummulitic limestone. Associated with these, a thin layer of the shells of a large, strongly marked six-ribbed *bivalve*, ill-preserved in carbonate of lime, was found at a few places close to the above-mentioned limestone. Shells in any part of the series

* From rough examination in the field, it is not easy even to say whether the fossil timber of the tertiary sandstone series is really exogenous or endogenous. This is not for want of specimens, but while these frequently present gnarled and knotted fragments, sometimes with appearances of branches having issued from within, the grain is generally straight, like bundles of parallel fibres, and as the cross section exhibits no structure, rings of growth or medullary rays are unseen. Some fragments of palm-like wood have been found, so that probably this timber may be of both kinds. No leaves, nor anything except thick fragments up to the diameter of considerable trunks, have been met with.

Specimens of these have been forwarded to Calcutta, but are as yet unexamined. The Salt Range specimens and those found here are identical.

are quite exceptional, and this is the only case of their occurrence known here.

Higher up in parts of the middle group, along with the timber abovementioned, numerous large fragmentary bones and occasional teeth or tusks occur in the soft greenish-gray sandstones of some localities; while towards the uppermost sub-division bone fragments are still to be met with, and have been found beneath the boulder sandstones of Makud, so that these osseous remains appear frequently, though sparsely, distributed through the whole series: reptilian remains apparently characterising its lower part here as well as at Subáthu according to Major Vicary.*

Conformity.—So far as the relative positions of the sandstones and clays to each other and to the nummulitic limestones are concerned, they are all conformable, but the fact of absolute and entire conformity of the whole series from the limestone upwards is not so clear. So much conformity as is indicated by perfectly parallel succession and by a short transition through highly calcareous sandstone (in some spots containing bone fragments) at the junction of these limestone and sandstone beds, (besides some other transitional features more limited in their range) may be found in any clear section. Where the limestone has all but died out, the part of it which disappears first is the lowest, and the upper limestone beds with those of the absolute junction continue till even these are gone and the contact layers alone remain to show that the succession continued the same everywhere, whether the limestone was present or not.

Again, the rocks of the sandstone series nearest to the limestone are always the same lower or 'Murree' rocks where displacement has not occurred. One peculiar band of small calcareous concretions disposed to weather separately, occurring over a large space close to the uppermost

* Quarterly Journal, Geological Society, London, Vol. IX, page 72, 1853.

layer of the limestone or to its place where absent from the section by reason of general thinning out of the whole group.

On the other hand, intimately associated with these evidences of conformity, there may be widely observed in the sandstone beds near the uppermost nummulitic limestone numbers of fragments, blotches, and pebbles of the upper *alveolina* and *nummulitic* compact limestone, or at least rocks exactly like these, and full of their fossils. The occurrence of these derived fragments in situations where the strong upper limestones have died away shows plainly that they must have come from some distance however small, and the only way that suggests itself to account for their presence without unconformity is that mentioned in the foot-note to page 57 regarding the similar occurrence of such derived pebbles down even in the basal portion of the nummulitic series.

Whether the explanation there given be accepted or not, the fact deserves notice, and, though considered insufficient to establish unconformity here, it is not against a state of things approaching thereto having existed, perhaps not very remote from the localities where the enclosed pebbles have been observed at various parts of the district.

These enclosed foreign fragments may be found over the whole district in the situations described, and it is known that they also occur in the same tertiary sandstone beds Cis-Indus in the Potwár plateau,* and along the base of these beds on the northern side of the Salt Range. Taking the whole broadly together, they may be said to range through a country 7,000 square miles in area, in which the junctions of the sandstone and limestone are repeatedly seen with the same conformity as noticed in this district, and if any total unconformity or discordance existed between the groups, it seems but fair to suppose that, along the many miles of boundary traceable through a region extending for 150 miles with the strike of the rocks, some evidence of excavations or

* Records, Geol. Sur., Ind., Vol. VI, p. 63. Somewhat similar rocks to those at the junction of the Trans-Indus limestone and tertiary sandstone are mentioned by Dr. Fleming at p. 353, and by Mr. Theobald at p. 670, of their papers on the Salt Range already quoted.

other erosive action upon the subjacent limestone rock, or some instance of complete discordance of stratification, would be found.

Conditions.—The great thickness of these tertiary sandstones, &c., and their endless alternation of arenaceous and argillaceous strata supposed to have been accumulated in shallow water, would point to a gradual subsidence of the basin, or lake, or sea which received them in order to allow of such a depth of beds being superimposed. A corresponding elevation of the Himáláyán rocks from the erosion of which they were probably formed may have taken place during a period which must have been protracted and longer still if the salt series and nummulitic limestone are all included, involving some uncertainty as to its early conditions when the waters, if not of the sea, must have at least been salt. Fresh water deposition may have succeeded, but there is nothing to define the exact place at which any change in this respect occurred, for the mammalian and fresh water reptilian remains could have been brought by rivers into the sea. And there is almost as little to mark the close of the epoch or link its geological events with those of recent geological time, the highest beds known having suffered denudation to an undeterminable extent, so that it is impossible to say what was the most recent conformable deposit of the period.

The boulder beds of the upper part of the formation, or what remain of them in this region, occupy situations which might favour the idea suggested in Mr. Medlicott's Memoir (so often referred to), that the boulders travelled through spaces approximately coinciding with existing lines of drainage, if their identity could be absolutely established with the rocks in the interior of this part of the Himáláyán region. The probability is strong that they were thence derived, and gathers still further strength from the upper beds being apparently the source of the Punjab stream gold, which is washed in a few localities in this region as elsewhere.*

* See Dr. Fleming's account in his Salt Range Reports.

Points indicating a general tertiary age for all the rocks.—If the rocks above described be considered collectively as a great consecutive series, there are some points connected with this to which attention may be drawn as favouring the idea that the whole belong to the tertiary period commencing with very early representatives of Eocene age.

The apparent intercalation of some purple sandstone and clay bands of the same aspect as those of the 'Murree group' with the nummulitic limestone, (though obscurity exists where disturbance and dislocation are so common,) would link the limestones to the beds above as much as the sequence to be found at the junctions which have been or will be described. Again, the red clay zone below the limestone, in its general color and aspect, bears so strong a resemblance to the red clays of the Murree group, that when accident brings the two into juxtaposition the clays are undistinguishable.

The occurrence of gray and white banded gypsum, such as may be found here, together with greenish-gray and red clays, often gypseous; nummulitic limestone, &c., in the lower 'Murree beds' of the Ráwál Pindí district, admitted to be Subáthú, as well as the presence of gray limestone beds with a peculiar lavender tint, and containing in both localities only *univalves* or *gastropoda* of a discoid form, is an association of similarities which, added to the prevalence of petroleum or other earth-oil in both cases, forcibly indicates that the greater development of the gypseous, saline, and calcareous series in this district belongs to the same early tertiary, otherwise called Subáthú, age.

Leaving the difficulty of accounting for the absence of older rocks aside where tranquil succession is apparent, as has been already pointed out, we may infer from the presence of the red muds, purple sandstones, greenish gypseous shales, gypsum, limestone, bitumen or petroleum, together with the evidence afforded by fossils and by salt in one case and saline springs in the other, a prevalence or recurrence of certain conditions at a period elsewhere known to be nummulitic, all tending to confirm the idea formed on first seeing the rocks, and each point adding strength

to the identification of the whole as one broad system of results from causes or conditions appertaining to Eocene times.

Superficial deposits.—These hardly require any special notice. Coarse atmospheric, detrital accumulations predominate, and especially in the Tíri valley are scarped at different levels, as if that river in its wanderings had at certain periods excavated its channel with greater rapidity than at others, its power to do this being of course influenced by the height of the river Indus. Large surfaces of the Bánnú valley are occupied by gray sand derived from the tertiary sandstones; this also occurs in the lower part of the bed of the Tíri Tauí and in a tributary nullah from the south. A well-defined series of thick stratified deposits flanks the hills east and west of (Súrdág) village, and may probably form part of a vast detrital talus said to flank the Súliman hills near Bánnú. Calcareous tufa is exceptionally rare, while alluvium proper seldom exists owing to the rapid fall of the streams; nor have the analogues of 'Kadirs' been observed, but the sandy finer earthy and sometimes kunkery materials occasionally assume somewhat the appearance of loëss, not, however, here eaten into labyrinthine '*Kudderas*,' as in the Potwár plateau, Cis-Indus.

IV.—EXTENSION OR NON-EXTENSION OF THE SALT BEYOND THIS DISTRICT.

One other point remains to be discussed before entering upon detailed descriptions of some of the sections to be found in the country, namely, how far the salt-beds of the series may be limited to the part of this region under British Government or within British influence.

From what has been previously stated, it will be seen that the rock-salt of the district *is one of the rocks of a series* which, whether considered as nummulitic or as part of the great tertiary system of the province, *is not necessarily bounded by any natural lines within the British Frontier.*

In the direction of the Manzullí or Threckanushpa range the clays and gypsum of the salt series hold westward along the frontier line beyond the last salt known, but the gypsum appears to be dying out, or its surface exposure lessening owing to the stratigraphical position of the adjacent beds.

To the northward of this place the nummulitic limestone looked upon as part of the same sequence continues also westward, forming hills nearly to the Kúram river, and to the southward, the axis of the Bahádur Khél, disturbances diverging from those of Manzullí embrace a wide area of newer tertiary rocks crowned by the crags of Kaffír Kôt in the Wazírí country.

There are indications in the endings of the nummulitic anticlinals at Suppurí and Luttummer that the axes of these are passing below a great mass of newer rocks which, overlying the limestone, would effectually conceal the salt, but that this state of things does not continue is shown by the recurrence of the limestone, forming a conspicuous hill within the Wazírí territory north of Bánnú. The aspect of this hill from a distance is all that can be remarked upon, and it looks as if it was an isolated exposure caused by an upward arch in the axis, beyond which the tertiary sandstones, &c., from the appearance of the ground, might be expected to come in strongly in the valley of the Kúram.

It is confidently asserted by the natives of the frontier tract that neither *Speenki* (gypsum) nor *Malga* (salt) occur in this Wazirí country, nor anywhere westward of the frontier line, yet Dr. Verchere, in his geological paper to the Asiatic Society, already quoted, refers (at page 20, 1867,) to red marl and gypsum at the hot springs of Sir Oba* (probably Sar-Obáé, west of Bánnú), which may belong either to the salt series of this country or of the Salt Range; perhaps the latter.

The existence of marl and gypsum, however, would be no evidence that salt was also present, though of course the exposure of its associated rocks would, in the absence of better information, favour the possibility of its discovery.

The tertiary sandstones, clays, &c., have evidently a wide extension westward of this district, and if the lower part of the series was anywhere exposed, the accidental or natural fall of a cliff or stream bank might bring salt into view, there being no reason why it should not occur in other places as well as within this district, nor can precise limits be assigned to such salt deposits in any particular direction on general geological grounds.

It would be otherwise if the salt occurred in unconformable outlying patches, the remains of larger deposits, which might have been denuded from off the face of the country. Here, on the contrary, as has been shown, the rock-salt forms the base of a disturbed series, members of which stretch far away to the westward, and the likelihood of its non-appearance in that direction depends largely upon the physical structure of the ground, the prevalence of the massive upper arenaceous rocks, and the absence of faults or such upward curvature of the strata as would have brought the basal beds within reach of erosive agency in

* The place is unfortunately not marked on Dr. Verchere's map, but from information kindly supplied by Major Johnstone, Deputy Commissioner of Bánnú, appears to be situated beyond the frontier south of the Dour valley, and south of the village of Sokhál, between the Dour valley and the Khisor nullah.

There is another 'Sarabee' at the north end of the Chichálí Pass, which is not supposed to be the locality meant.

hills, valleys, or ravines—the fact being always borne in mind that even if these erosive agencies exposed the gypseous series, as seen in this district, the salt need not necessarily be present, for it may have thinned out and entirely disappeared.

To the eastward the extension of the salt and gypsum series, if it continues in that direction, is buried beneath the sandstones and clays of the Potwár country, some indications of it perhaps existing (as suggested) in the gypsum of the Subáthu zone near the hills to the northward, or in the source of a brine spring at Kalra close to the southern foot of the Bakrálá ridge, not far from the Grand Trunk Road.

North of the villages of Láchí and Sireemeyla, both in this salt region, salt is unknown, but some of the streams issuing from the gypsum on the southern sides of the Gúrgúrlot hills are said to be saline, at no great distance from the salt-bearing tract.

Southward of the district, too, in the Sheen and Lawággar mountains, rock-salt is likewise unheard of westward of the Lún nullah, unless its existence be indicated by some saline springs many miles to the southward recorded by Dr. Fleming as “issuing from saliferous sandstones under carboniferous limestone near the village of Bahádur Dôk,” not far from the junction of the Kúram with the Indus.* The Lún nullah salt is considered, for reasons already given, to belong to the Cis-Indus salt series, and any saline sources for these springs would from their description be referable to the same much older series rather than to that of this district.

If then the country to the north and south, where the rocks are known to be greatly disturbed, and lower beds than any found in this district are exposed, shows no extension of the local salt deposits, the presumption that they extend visibly to the west would be unreasonable, particularly when, as far as could be seen in this direction from the high-

* Dr. Fleming's Report, Jour., As. Soc., Beng., 1853, p. 260.

est hills,* the ground appeared to be mainly occupied by the soft upper tertiary sandstones, &c., in great undulating masses.

It is extremely unlikely in a country so traversed by herdsmen, if rock-salt were visible, that even small exposures of it would long escape their notice, or remain generally unknown, and, on the whole, it may be said that there is nothing in the geological aspect of the question to warrant the conclusion that salt exposures exist beyond the frontier, though its presence is quite possible whether exposed or not, and quite as impossible to foretell.

Had the existence of nearer salt been known during the great time these deposits have been worked, people would hardly have come all the way from Kábúl and other distant places with unladen animals to buy it here, and this seems a stronger argument against its occurrence in trans-frontier regions, than any geological reasons to the same effect, or to the contrary, bearing upon this most important point with regard to the British monopoly of the salt.

* Far beyond the distance at which any rocks could be recognised, some high mountains in the country on the other side of the Káram are probably formed of crystalline rocks, for granitoid *chuckies* (*mill-stones*) were seen among the wandering Waziris, who said they had brought them from that direction.

PART II.
DETAILED DESCRIPTIONS.

PART II.

DETAILED DESCRIPTIONS OF PARTS OF THE DISTRICT, WITH SKETCH SECTIONS ILLUSTRATIVE OF ITS STRUCTURE.

As the physical features of the ground arrange themselves naturally in four or five principal groups, and as these best exhibit the structure of the ground, it is intended to adhere to this natural arrangement in describing this structure or alluding to those places where noticeable points occur. These descriptions may therefore be conveniently arranged under the following divisions:—

- 1.—*The ground westward of Lachee or Láchi.*
- 2.—*The northern watershed of the Teeree Towey (Tirí Taní) basin from the neighbourhood of Murdán Khél eastward by Malgheen (Málgín) to the Indus, and the hills about Weejoosum (Wijásum) and Drubbokus.*
- 3.—*The nummulitic ellipsoid from Manzullí and Threekánushpa (Turkhái nuakhbo) to Bánda on the Kohát and Bánnú road; also the ridge thence to the Jatta ellipsoid near Zunuk: the nummulitic ellipsoid of Jatta and the imperfect one of Saya (Séya) Malgheen (Málgín) Salt Quarries.*
- 4.—*The hilly ranges and their neighbourhood from Bahádur Khél and Soordag (Súrdag) country to Nandrukki and Hokunni mountains.*

The plains and valleys between or adjacent to these features can be referred to where necessary as the remarks progress.

(For convenience of reference the spelling of the map will be generally adopted in the following pages, the official spelling being added in brackets).

1.—*The ground westward of Lachee.*

Lachee (Láchi), a considerable village on the road from Kohát to Bánnú, possessing an enclosed fort or structure which answers the double purpose of travellers' serai and rest-house as well as military post for frontier force. The place seems to be chiefly remarkable for the manufacture of saltpetre from the village refuse and soil, and therewith gunpowder of a coarse kind used for blasting at the salt quarries.

The country may be briefly described as hilly to the west of the village, there being some four or five nearly east and west anticlinal axes of the strata coinciding with as many eocene limestone ridges. There are two considerable valleys opening towards, and other smaller ones occupied by, the tertiary sandstones, &c., these valleys being themselves hilly rather than flat, and having their heads towards the westward, so that the sandstone ground becomes deeply embayed among the nummulitic limestone hills.

Close to Lachee (Láchi) one of these limestone ridges terminates, that particular anticlinal axis becoming depressed below the level of comparatively open ground to the east just before the ridge sinks; however, in perhaps the least likely situation for such an exposure, the limestone beds have been removed by erosion, displaying a good deal of apparently somewhat displaced gypsum in which deep hollows mark the sites of former salt quarries, the nearest or most accessible in the district to Kohát. None of the salt is now visible, nor is the place specially suited for mining, yet in other localities it would doubtless be considered a valuable possession.

Westward from the old salt-pits the ridge exhibits its anticlinal structure strongly, being covered with a thick sheeting of hard *Alveolina*

and *Nummulite* limestone sweeping boldly downwards and plunging beneath highly inclined beds of the tertiary sandstone series along the foot of the ridge on both flanks. Close to the limestone the beds are steady and nearly vertical, but further out in the valleys contortions are seen.

Along the sides of this Lachee (Láchí) ridge a feature not uncommon may be observed at the junction of the limestone and sandstone. It is this—the strong and steeply dipping limestone shows a low scarp on the dip side as if it had in places given way under the tension accompanying its contortion, and the débris from the face of the cliff thus produced, added to that which travelled down the slope, renders it almost impossible to observe absolute contact at such localities.

The following succession was observed close to Lachee (Láchí) old salt-pits:—Fig. 3.—

6. Nummulitic limestone.
5. Dun compact *Alveolina* limestone.
4. Darkish-gray limestone with *Alveolina*, &c.
3. Talus showing débris of soft light coloured gypsaceous clays, remains of a red clay band, &c.
2. Gypsum, whitish and gray, overlying, *unseen*.
1. Rock-salt.*

Proceeding up the long valley from Lachee (Láchí) westward by Ghoráudí valley, Tsunda, the stream of which becoming distributory apparently loses itself in the plains near Lachee (Láchí), the tertiary sandstones striking with little variation east and west are seen to be everywhere vertical, and as the valley contracts, high anticlinal or contorted limestone ridges enclose it on each side.

Of these ridges that to the north, or rather those, for there are two, exhibit the antiolinal curvature plainly like that at Lachee (Láchí), but the continuation of the latter south of the valley has a more complicated structure from the vicinity of

* With reference to the existence of the rock-salt at this locality, see Appendix.

Kole Sír, where portions of the tertiary sandstones rise on the hill obliquely, nearly connecting these beds with those of the valley south of Lachee (Láchí) ridge. This is apparently accompanied or caused by dislocation as well as extreme crushing and crumpling of the beds. A

Inlet of tertiary sand- couple of miles to the westward near the village
stones, &c. of Ghoráudí, a deep ravine from the nummulitic
limestone hills south of the valley is occupied by the purple and gray
sandstone and red clay of the tertiary sandstone series, apparently
brought into this strange position by a small divergent synclinal curva-
ture closely compressed and faulted.

Ascending the hill above Ghoráudí, immediately upon leaving the
tertiary sandstone, &c., of the Murree group, and
Hills south of Ghoráu- crossing a small talus of limestone débris, the
dí. nummulitic rocks whence it is derived may be observed cropping out
strongly from the hillside instead of presenting an inclination more in
conformity with its slope, as is the case eastward of the narrow faulted
segment of the tertiary sandstones just now mentioned. On gaining
somewhat higher ground above, the strong nummulitic limestone is seen
to undulate boldly all over this part of the ridge, presenting numerous
scarps to the northward, which were well marked standing out from
snow that had lain some days when the place was visited. On the
opposite side of the valley, in a rather north-westerly direction, the smooth
anticlinal surfaces of the hills became broken, and bands of red clay
appeared intercalated with the limestone.*

Continuing southward into the lower part of the Leeloohan
(Lílúhán) Durrá or valley, a deep and narrow
Leeloohan (Lílúhán) glen, these red clays were found high up on the
Valley. southern sides of the hills cropping out among the
contorted limestone beds, and were recognised as parts of the red clay

* It is extremely doubtful if these red clays have any relation with the red zone. They resemble it closely, but present a strong appearance of interstratification with the limestones.



Fig 3 in the section of Limestone

Fig 5 Section in Gorge at Munda Kheyl



near the mountain at Esh

Section of the hills north and south near Gherandi



Fig 7 Section 1 1/2 to 2 Miles NNW from Irambhey

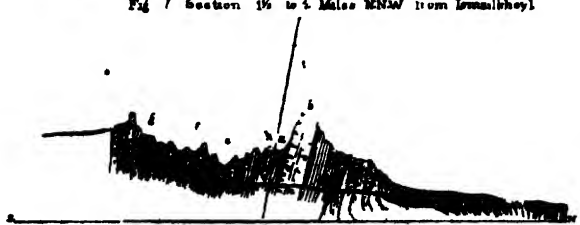


Fig 8 Section at Karpura melina



Fig 9 Section in the hills south of Karpura

zone found everywhere beneath these nummulitic limestones, their exposure here being probably aided by obscure faults of no great amount. Before reaching the Leeloohan (Lílúhán) valley, as well as within it, the tertiary sandstones are met with again, separated by a rib of the nummulitic limestone. In this valley, for some miles

Tertiary sandstones in-
folded and faulted.

above Momee (Momi) Khél, the sandstones and clays are vertical, striking up the glen, along the southern side of which the limestone rises abruptly with a scarped face as if separated by a fault from the sandstone beds.

Above this feature there is a small exposure of gypsum among the limestone hills south of Shukkar Khél between the Leeloohan (Lílúhán) glen and the larger Teeree (Tíri) valley. The general section across the hills mentioned is shown in Fig. 4. 1. Red clay in 2, Nummulitic limestone. 3. Tertiary sandstone and clay. F. Faults.

This small section* of some four or five miles in length will convey an idea of the frequently complex and highly contorted or dislocated state of the nummulitic and overlying rocks in this country. At the first glance one might suppose the vertical sandstones the oldest, and that the limestones had been removed from above them in the valleys by denudation, but this is shown not to have been the case, independently of other proof, by the folding of some of the same vertical rocks into the section at the north side of the Leeloohan (Lílúhán) glen.

Structure of section.

Westwards towards Deh Oomar (Dé Úmar) the hills rise and the nummulitic limestone spreads out, rolling over them with one larger synclinal than the rest, corresponding to the termination of the Ghoráuí valley. To the north and north-westward high nummulitic ground only could be seen, and it was asserted that in these directions the tertiary sandstones were rarely to be found among the hills or in the Bungush valley.

* This and following sections being diagrammatic do not always follow straight lines as it has been sought to express all general or prominent structures near them.

2.—*The northern watershed of the Teeræ Towey (Tíri Tawí) basin and hills from Murdán Khél eastward by Weejoomsum (Wéjúsúsum) and Drubbokus nearly to the Indus.*

The nummulitic limestone as usual forms the high ground overlooking the (Tíri) valley near the Murdán Khél: yet here, though but ten miles apart, the sections differ much from that last given; a singular T-shaped glen, opening through a rocky gorge southwards into the larger valley near that village, having been eroded from a soft clayey and sandstone group in the nummulitic rocks unseen before and which predominates in this vicinity.

Besides the occurrence of different rocks, the usual amount of inversion: Murdán representation prevails in consequence of the inversion of the beds, a feature strongly developed here. Here, too, a band of rocks so identical with the lower tertiary sandstones as to be undistinguishable appears with all the aspect of intercalation between the nummulitic limestones, and follows their outcrop, dividing one band of these limestones from another.

In the gorge near Murdán Khél the arrangement shown in Fig. 5 may be observed—

Beds inverted.

8. Purple and gray sandstones and purple clays at mouth of the gorge dipping northward at 30°, and upwards, tertiary sandstones.
7. Thick *Alveolina* limestones dipping north at 55°.
6. Thinner and darker coloured limestone, nummulitic.
5. Bluish-gray coarse sandstone and purple clays identical in character with those of the lower tertiary sandstones.
4. Limestone thinner bedded than 6 and 7, darker and more shaly.
3. Lumpy, dark-coloured limestone with beds of platy shale.

In these a band of coarse light purple conglomeratic sandstone occurs, *apparently overlying* which only odd beds of limestone occur here and there in sandstones often conglomeratic with pebbles of limestone and crystalline rocks. The limestone bands contain both *Nummulites* and

Alveolina, the latter frequently, and the sandstone portion of the group may be from 300 to 400 feet in thickness.

Hard, greenish-brown, clayey, calcareous bands begin to appear, and at a distance of 15 feet below (but apparently above) fossiliferous nummulitic limestone, sandy beds contain pebbles of limestone enclosing *Alveolina* and *Nummulites*.

At this point in the section the glen within the gorge is reached and found to be occupied mainly by gray clays weathering of a greenish colour, often covered with a white saline efflorescence, and, though undulating at lower angles, presenting a conformable transition from themselves to the sandstone series at the head of the gorge.

It is one of the most complete and delusive cases of the inversion so common in the district; all the aspect of the Delusive appearance of section, section from the lower tertiary sandstones to the south indicating an ascent to higher beds, among the highest of which derived pebbles of limestone resembling that in the section would be met with; and yet this cannot be an ascending section, for the same nummulitic limestone may be found both at Lachee (Láchí) to the east and near Durshái to the west, folding over anticlinal axes, and passing beneath the tertiary sandstones, &c., which are thus shown to be inverted here. One way of accounting for the fossiliferous limestone pebbles enclosed in contemporaneous rocks has been noticed already at page 57.

Between three and four miles to the eastward of the section just described, the section from the Teeree (Tírf) valley, Shah mountain section, up to the top of Sháh mountain also exhibits the inverted order of these beds with somewhat different features, the gypseous series being introduced by a fault or faults, and even more of these than are apparent being very possibly present.

Fig. 6 shows the section up to Sháh mountain from plain to south in the Teeree valley. The figures, &c., are explained below:—

2. Gypseous series. 3. Red clay zone. 4. Nummulitic series. 5. Tertiary sandstone, clays, &c. (Lower). F. Faults.

k.—Tertiary purple sandstones, gray sandstones and purple clays much contorted.

j.—Nummulitic limestone with hard, gray, and white marly lumpy layers; some slightly granular layers contain *echinoid* fragments and spines, *nummulites* rare.

i.—Bright red clay.

k.—Pale purple or brownish sandstone and red clay.

g.—White, marly, thin lumpy, and thin *alveolosa* beds, and strong limestone. (This limestone band is apparently cut out by a fault to the east).

f.—Alternations of sandstones and red clay.

e.—Pale brown sandstone weathering dark brown and olive sometimes containing pebbles. Towards the upper part of the hill beds of clay of a greenish olive or gray colour predominate. Limestone pebbles occur in the sandstones, and there are small *nummulites* both in these and in the matrix.

c.—Red-clay zone.

Fault or Faults here.

{ *b.*—White and gray gypsum dipping generally to the north.

{ *a.*—Greenish clay band in the gypsum.

The gypsum is overlaid by red clay (*e*) which possibly represents that at *f* and *i*, and this is succeeded by the strong nummulitic limestone (*d*) which forms the summit and northern surface of the hill, passing downwards into the Leeloochan (Lilúhán) glen.

On the western side of Sháh mountain overlooking the eastern head of the T-shaped glen previously mentioned
Shah-drung salt local- ity. is the site of the Shah-drung salt in connexion with the gypsum, and just beneath the continuation of the red clay band (*e*) in the above section.

The difficulty of understanding this section by reason of the inversion of the beds is increased by the dislocation of the rocks. Two zones of bright red clay not seen in the Murdán Khél section occur here at (*f*) and (*i*); one of these may be the representative of the red band (*c*) below the nummulitic limestone, but it is difficult to say which. In this section the reversal is even more pronounced, the nummulitic beds *j* absolutely resting with some horizontality for a short distance upon the lower tertiary sandstones, &c., and purple sandstones resembling these are found at (*k*) in the same place as the band (5) in the Murdán Khél section, and with the same appearance of intercalation, but less like ordinary tertiary sandstone. The positions of the rocks are so strange and there is such evident dislocation, it can only be suggested that the

Dislocation as well as inversion obscuring the section.

Swani Sir part of the section once stood higher relatively to the rest; and after it subsided, the southern portion also sank, most probably along another line of fault. The ground is, however, very obscure, and where the best sections might be expected to be found, is overgrown by grass, *Kao*, and other bushes; a most exceptional occurrence in this country.

Less than two miles eastward of this section the gypsum is seen to occupy the interior of an anticlinal fold or nose of the nummulitic limestone, bright red clay intervening between these two as shown upon the map. Some of the brown conglomeratic sandstones appear here also closely associated with the red clays, but so obscurely placed that it would be rash to say which was the newer rock, the probability being, however, that these brown sandstones are next older, in the local series, to the red clay over the gypsum, and thus older than the nummulitic limestones. The exterior portion of this anticlinal towards the Teeree valley shows nothing of anticlinal form, the nummulitic limestone dipping steeply the wrong way and presenting an escarpment to the south. Within the apex of the curve and on its northern side the beds assume their proper order, passing beneath a portion of the lower tertiary sandstone series, which is faulted into a small valley between the anticlinal and the western part of Shah or Swani mountain.

For six miles to the eastward of this place, as far as the mouth of the Leeloohan (Lálúhán) glen, the nummulitic limestone presents a strong scarp to the south, rising above crushed and contorted folds in the tertiary sandstones along its base, these sandstones, where a general dip can be observed, appearing to incline towards rather than away from the limestone. The feature is suggestive of a fault, but where inversion prevails to such an extent as it does here, this is quite sufficient to account for the anomalous positions of the rocks, though faulting may also occur.

The portion of the Teeree (Tíri) valley overlooked by the hills lately described is open, but not level; most of the Detrital deposits in Teeree (Tíri) valley. streams expose the tertiary sandstones, and the ground between often presents a considerable amount of shingle, gravel, clay, and such superficial accumulations arranged in the form of terraced hills, somewhat after the manner of the 'Karewah' of Kashmere, but not of equal extent.

One broad group of hills occupying most of the valley from two to four miles east of the town of Teeree (Tíri) is Nearly horizontal beds in valley. instructive, showing how much less disturbed the rocks are in the centres of the synclinal valleys of the country. The sandstone and clay beds of these hills are in places nearly horizontal, or slightly inclined from the middle of the ridges on either side to a common axis near the middle of the valley, and as is common, in such beds so placed they present strongly marked escarpments on the crop side.

The hills culminating in Kole Sír present a very complicated structure, sharp anticlinal and synclinal folds having Kole Sír: complicated ground. A salt locality. suffered much disturbance and dislocation, in consequence of which there are numerous exposures of gypsum, the green clays associated with it, the red clay above it, and the nummulitic limestone overlying this, while the tertiary sandstones, &c., are found at different elevations around. Here also south-eastward of the summit where the largest exposure of the gypsum occurs is the rock-salt locality of Solthorbagar, described in the appendix.

Along the southern slopes of the hills the limestone appears to have slipped from its place sometimes *en masse*, and sometimes to owe its position to faulting. The sandstones of the valley, often of a hard texture and ash-gray colour, associated as usual with purple clays, appear close to the bases of the hills and for a short distance up their slopes. As usual also their dip

is reversed, leading the beds at high angles below the nummulitic limestone, but the junction of the two groups is generally concealed by débris of the latter rocks. Crossing this limestone the following section was found everywhere inverted:—

	Feet.
8. Thick, compact <i>alveolina</i> limestone, white and yellow, very lumpy in places, and containing clusters of coral fossils impacted, and difficult to distinguish, about	30 to 50
7. Thin, lumpy, and marly light coloured limestone full of fossils, <i>nummulites</i> , <i>oysters</i> , &c.	20
6. Strong limestone full of very small nummulites	6
5. Thin and thick regular limestone with few fossils, semi-colic looking	40
4. Earthy-gray limestone with greenish shales, <i>nummulites</i>	15
3. Remains of a band of cherty limestone of dark colour containing white fossil fragments, no <i>nummulites</i> found	21
2. Red clay	15
1. White, gray, and variegated gypsum occupying 60 yards of horizontal space, may be	100

Crossing this gypsum mass at its northern side was found a thick zone of greenish clays not seen to the southward, and beyond it a thinner band of gypsum occurred, all dipping steeply to the north. Over the latter gypsum, the red clay previously met with was much more largely developed, and immediately succeeded by nummulitic limestone forming the crest of the ridge, the débris from which largely concealed the clay and gypsum just below.

Although there is a want of continuity, and the greenish clay would seem to be capriciously distributed through the gypsum, the steady high northern dip from the plain or valley to the south as far as the gypsum here must be considered inverted, this gypsum forming the centre of an overthrown anticlinal curve. The dip continues still high to the north, but after leaving the gypsum the order becomes natural; the nummulitic limestone of the crest is succeeded by the hard light-coloured *alveolina* marble, and the tertiary sandstones, clays, &c., which seem buried beneath the whole section, appear at top in the valley between this place and Lachee (Láchi).

From the vicinity of the old salt-mines above mentioned, this gypsum stretches eastward between two bands of the limestone to a point due north of Ismaíl Khél, its general arrangement being that shown in the sketch section (Fig. 7), crossing the ridge, where the latter is comparatively low, north by west from the last named village. The numbers are as follow:—1. Gypseous series. 2. Red clay zone. 3. Talus débris and concealment. 4. Nummulitic limestone series. 5. Tertiary sandstone and clay series.

Section.

Inverted order.

- a.—Purple sandstone.
- b. c.—Purple and gray pseudo-conglomerate in red clays, (Murree beds), calcareous.
- d.—*Alveolites* limestone.
- e.—Green gypseous clay with hard gypseous layers, vertical.
- f.—Strong, flaky, solid, white gypsum.
- g.—Pale-greenish clay, with hard lime bands (h).

Natural order.

- c.—Purple and gray sandstone and red clays (Murree beds).
- a.—Hard tan and whitish *alveolites* limestone or marble.
- e.—Red clay, very red above, purple and red with sandy ferruginous layers (f) below.
- h.—Solid gypsum, reddish and flaggy above with black bituminous layers.
- j.—Grayish-green clay.

i.—Strong white gypsum.

This section is one of many which may be found in the country—showing but an inadequate representation of the former state of things. The double band of limestone with the gypsum between is a broad fact consonant with the structure of other places, but between these limestones the section, though rather well exposed, remains obscure, so that it is difficult to say where the axis of curvature may be. The red clay zone below the nummulitic limestone is strongly displayed to the north, (as in the preceding section), but what there may be of it to the south is concealed, and the nummulitic limestone itself is apparently thicker at the north than at the south exposure. If room for these beds to thin out to some extent over the curve (the distance across which is only about half a mile) be supposed, the difficulty would become less, but in its centre, where the bands on opposite sides would be much nearer each other, an even greater disparity is found, the gypsum and clay alternations not answering to each other. Crushing, compression and tension or traction

may have greatly modified appearances, yet still there would seem to have been much original irregularity in the arrangement of the different bands without the introduction of extreme dislocation by faulting which appearances would scarcely justify.

About two miles east of this section the east and west run of the ridge is interrupted by a sudden crush as it were from force exerted in these directions, the gypsum bulging out after becoming narrower even than where the section runs, and then being rapidly lost sight of eastward, where the ridge is formed by a thin rib of the limestone in continuation with the northern band shown in the section above.

There are some red clays seen at intervals among the débris on the south side of the narrow rib of limestone, but the Kurrupá incline. second limestone band has disappeared, vertical purple and gray sandstones taking its place, associated as usual with red and purple clays.

The road from Kohát to Bánú crosses this range, and ascends by a steep incline to a higher level at a place called Kurrupá, where there is a boorj or tower used by the men who convey the district post.

The nummulitic limestone here appears much crushed, its thickness reduced to a few beds of the hard *alveolina* limestone, and its dip has changed in the opposite direction, the rocks here underlying to the south at a high angle where not vertical; though not far from the northern end of the little pass, they assume open curves. Fig. 8 shows this section at Kurrupá incline. *a*.—Red clay. *b*.—Nummulitic limestone. *c. g*.—Tertiary sandstone, &c. *h*.—Probable fault.

d.—Soft, greenish sandstones and pseudo-conglomerate and purple clays.

e.—Red clay.

b.—Hard nummulitic limestone.

a.—Bright-red clay (possibly the band below the nummulitic limestone?)*

g.—Soft, greenish, and gray sandstones, and red and purple clays.

f.—Conglomeratic bed containing crystalline rock pebbles.

c.—Gray and greenish sandstones with predominating red clays.

* In such a case as this, it is often impossible to distinguish between the brighter red clays of the tertiary sandstones and the red zone below the nummulitic limestone.

One peculiarity observable here is the occurrence of a conglomeratic layer *f* containing scattered pebbles of quartzite and other crystalline or hard metamorphic rocks among beds which, both from their place and aspect, would seem to be some of the lowest of the tertiary sandstone series. Fragments of these older rocks have been mentioned as characterising the higher stages of the series, but their appearance below is quite exceptional, at least in the form of pebbles, or blocks.

The narrow rib of limestone continues eastward for about seven miles, forming the backbone of the ridge, which is flanked by vertical and disturbed sandstones and clays similar to those at Kurruppá. Towards the end of that distance it becomes slightly wider and terminates in an anticlinal 'nose' of considerable regularity, the axis of which sinks into the adjacent lower ground, the ridge disappearing at the same place, and the sandstone beds successively embracing the curved surface of the highest limestone layer.

The aspect of the ridge in the neighbourhood of Kurruppá would never of itself suggest that the limestone band belonged to part of such a simple curve as is seen here. To interpret such sections by appearances would manifestly lead to serious error, and the difference between these appearances and the fact will convey some idea of how enormously distorted is the stratigraphy of the district.

Returning eastward by Kurruppá to the hills north of Ismaíl Khél, we find another horse-shoe anticlinal termination to the nummulitic limestone with which they are covered. Nothing in the general aspect of this hill at the place would suggest its structure, but at a little distance from the end, which, unlike the last, is presented westward, the sandstone and clay beds are found to come round in a bold curve, the southern side of which has a more gentle inclination in that direction than the northern

North of Ismaíl Khél
another anticlinal.

to the opposite, some of the beds there being vertical or even pushed over beyond the perpendicular so as to underlie to the south.

To the eastward the anticlinal opens, its southern side disappears, being probably buried by a fault, and the northern part of the curve coincides with the ridge to the eastward, passing by Shúwukí. Just where the southern limb ends, a quantity of gypsum is seen within the curve at a place where 'salt mines' are marked upon the map. Here the ground looked as if it might once have been disturbed artificially, but none of the natives could give any information as to salt mines having been formerly worked at the spot: the presence of salt here is notwithstanding by no means an improbability.

A north and south section here through a little pass, used as a short-cut from the Jatta salt mines to Lachee, is given in Fig. 9.—

2. Gypsum. 3. Greenish clay with calcareous layers. 4. Variegated purple, red, and green clay with sandy bands. 5. Dark, cherty limestone. 6. Shaly, nummulitic limestone. 7. *Alveolites* limestone. 8. Very red clay. 9. Soft, greenish, and gray sandstones with a few harder bands and red clay beds. F. Fault.

This section, like that north north-west from Ismaíl Khól, is inverted, and liable to be misunderstood without due weight being given to the prevalence of inversion in many parts of the district.

Approaching the Little Pass from Kurrupá, ridges of soft, greenish sandstone highly inclined to the southward are met with in the little plain to the north. Clays among them are not much seen, being apparently concealed by surface deposits while the sandstones project. Similar beds are seen at the base of the ridge near the entrance of the pass, and higher up on the ridge close to the limestone deep red clays appear, much overshot by yellowish or buff débris from the latter. The limestone first met with is of the hard *Alveolina*-bearing kind, associated southward with more shaly layers containing *Nummulites*. All these beds dip to the south at 45°. Several yards further southward is a strong dark band of cherty limestone dipping

in the same direction and at the same angle. The chert of this band is white, and the limestone contains some obscure black fossil fragments, and granular knots or nodules. In the stream bank below the pathway as though overlying, at a little distance, the cherty limestone, are variegated purple, bright-red, green, gray, rusty, sandy and clay layers (14 in the section), and just beyond these variegated beds in the more open ground are hillocks of red and greenish clay with masses of contorted gypsum. Close to the southward of this some gray clays weathering greenish contain calcareous, lumpy, fossiliferous layers with *Cones*, *Oysters*, &c. Associated with these are red and gypseous clays with layers of deep liver-coloured sandstone, undulating over the ground with knolls of gypsum appearing from beneath the red beds, being overlaid by nummulitic limestone forming small hills, in the sides of which red débris is intermixed with the limestone detritus. The plain here between the pass and the Jatta hills is flat, but in the deeply cut river and stream valleys the soft, gray, greenish, and bright-purple beds of the tertiary sandstone series re-appear, with one very bright-red zone of clay, 150 feet thick. They strike east and west, and are either vertical or at high angles, generally dipping to the north, but show some greatly compressed synclinal curves.

From this place eastward, to and beyond Shúwukí, the nummulitic limestone is greatly disturbed, often quite vertical
 Shúwukí limestone disturbed and reversed. or reversed above the tertiary sandstone on the northern flanks of the ridge, and with a talus of limestone débris upon the other, allowing little to be seen besides an occasional protrusion of gypsum.* The limestone is about 100 feet in thickness.

The part of this ridge between Kureerosum (Kurírosom) and Sooddul (Súdul) close to the termination of the smaller ridge from Kurruppá is a focus of intense contortion broken through by faults. The simplest
 Focus of contortion and faulting near Sooddul (Súdul) and inverted limestone capping.

* The Jatta ellipsoid close to this part of the ridge described will be found mentioned below.



•• Fig. 10. South by west from Soodul

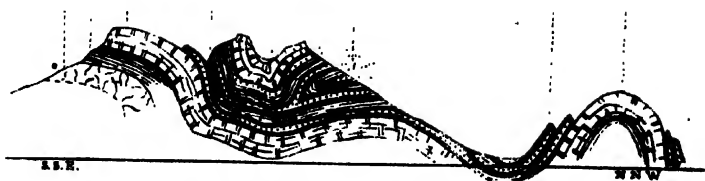


Fig. 11 South by west from Soodul

of these contortions is an oval, quaquaversal, dome-shaped sheet of the nummulitic limestone, just south of and about a mile distant from Sooddul (Súdul) village; but even this is faulted to the east, and sends a narrow band of the limestone southward to join that of the main ridge. The latter between this place and Shúwukí shows the nummulitic limestone on its northern side as a boldly curving convex sheet descending below the sandstones of the valley, but between this boldly curved sheet and the dome-shaped hill, a portion of the limestone is absolutely inverted so as to form a small cap upon a summit of the ridge which is mainly composed of contorted tertiary sandstones and clays. Fig. 10 is a diagrammatic sketch of the place from the dome-shaped hill, and Fig. 11, a section south by west from Sooddul (Súdul).—

2. Gypsum. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c.

The contortions necessary to produce this result are difficult even to imagine. If a second band of the nummulitic limestone were admissible, it would make things easier to comprehend, but no such second band was observed in the vicinity, and where there are so numerous evidences of extreme contortion, compression, and inversion in the district, it may not be too much to suppose this, one more among many strange cases of the strata being overthrown. The cap is a very small one; hence, perhaps, the difficulty of connecting it with curvature of the adjacent beds, but it must be remembered that the distorting forces which have operated in this district were sufficient to produce extreme results, and force the rocks into the most anomalous positions.

Another instance of this is not far to seek, for within two miles to the eastward there are again obscure cases of superposition of the nummulitic limestone upon the lower tertiary sandstones at a prominent peak upon the crest of the ridge due north of Kureerosum (Kurírosum). The very aspect of this conspicuous knob, even from the village named, tells that it is of limestone,

but the tertiary sandstones may be plainly seen beneath intervening between it and the limestone which forms the crest of the hill.

On ascending to the spot, the escarpment of the southern side of the ridge is found (as usual along here) faced by a talus of débris, from which project some slipped and broken fragments of the limestone which forms the crest. Just beneath the 'edge' are traces of the red clay zone quickly succeeded by the nummulitic limestone of the scarp. This is at first nearly horizontal, but curving downwards becomes perfectly vertical here and along the northern side of the ridge towards the village of Malgheen, (Málgín). Following the curvature of the limestone are perfectly parallel bands of purple sandstone and clay with filmy, metallic *slickensides* as in many other exposures of the 'Murree group' or lowest of the tertiary sandstone series. At the contact of these 'Murree beds' with the nummulitic limestone is a band formed almost entirely of or containing very numerous small concretionary nodules of brown hæmatite elsewhere seen in a similar situation. These beds form the base of the peak, expanding also on either side as a thin patch to the west, but much thicker to the east. At more than half way up the side of the peak its capping of craggy *Alveolina*-limestone is reached, and the *apparently* lowest portion of this in contact with the sandstones is found to be a brecciated-looking bed very commonly forming the *uppermost* layer of the nummulitic limestone, and here containing the hæmatitic nodules again, as noticed at the normal contact between the limestones and sandstones beneath.

The capping is entirely of the hard *Alveolina* limestone, greatly weathered and not more than 25 feet thick, if so much. A smaller similar outlying cap occurs immediately to the north, and another longer one north of it, close to an anticlinal convolution of the ordinary limestone, ending suddenly close to the place, and used by the Mussulman natives as a conspicuous point whereon to light their signal fire, signifying that the new moon has been seen and the fast of the Roza accomplished.

Alveolina limestone.
Two other such outliers.

Figure 12 is a sketch of the place in plan, and as viewed from the latter point. Fig. 13 gives section north of Kureerosum (Kuriferosum).—
 2. Place of the gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone series. F. Faults. 4 A, 4 B, 4 C. Nummulitic limestone caps.
 And Fig. 14 shows the caps of limestone north of Kureerosum (Kuriferosum).—

A. Limestone. B. Sandstone and clay. C. Débris. D. Fault.

These three cappings of limestone lie within a distance of from 80 to 100 paces. The two southerly ones appear shaken and somewhat out of place rather than presenting complete conformity to the sandstones on which they rest; the contact of the other looks more natural, so that a second zone of nummulitic limestone was sought for, displaced fragments of which might have formed the other two caps. No such second parallel band of the limestone, however, could be observed anywhere in the vicinity,

Fault. and where so much rock is exposed, if it were present, it could hardly escape notice. A fault which

may have some possible connexion with the complexity here runs from west to east between the most northerly capping and the limestone anticlinal-turning north-eastwards apparently, for steeply dipping beds of the sandstone group run directly at the end of the curve within a short distance to the east, as shown in the sketch plan.

Red clays: limestone.

Along this fault in a narrow ravine to the westward red clays are exposed as if cropping from underneath the nummulitic limestone, which close by to the north has lost its anticlinal curvature and forms a perfectly vertical rib. Another fault may perhaps run parallel to this between the two southern limestone caps accounting for the sudden change in the dip, from having a low northerly inclination beneath the two northerly outliers to vertical beneath that side of the highest cap.

Probable fault.

The whole strike of this part of the ridge sets straight at a curved part of the escarpment to the west as though to run against the outcropping ends of its beds, and

Another a crossfault.

the dislocation at the junction would seem to require more than one fault to account for the positions of the rocks, the red clay zone, the gypsum, and thick greenish-gray clays of the gypseous series being all forced into strange positions by faulting or slippage, or both.

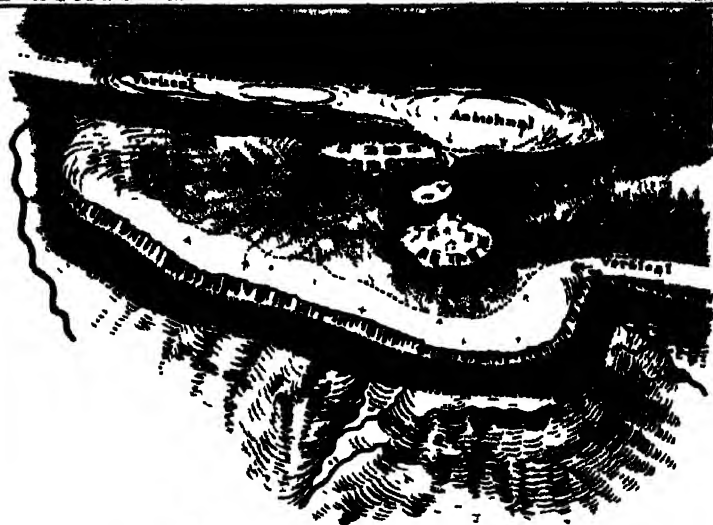
From this place, for many miles to the east, considerable regularity prevails, and the ridge presents the same features,—
 Regularity to eastward
 along outcrop. a vertical rib of nummulitic limestone forming its centre and crest flanked on the north by equally highly disturbed or vertical sandstones and clays, among which a purple tinge predominates, and on the south by a steep talus covered with limestone débris, occasionally showing some protrusion of gypsum or some landslipped masses of the limestone from above, or from its colour indicating the presence of the red clay zone beneath the detritus.

It maintains this character on the south side the whole way to the Indus, where it suddenly disappears, but on the north in the vicinity of Turwábeyrá (Turwábérá) it becomes connected with another parallel mountain about five miles in length, both rising together to a much greater elevation than the rest of the ridge.

All round this other mountain, one end of which overlooks Wee-joosum (Wíjúsúsum) and the other Drubbokus, the rocks and their arrangement are plainly visible.
 Mountain between
 Turwábeyrá and Drubbokus. Along its whole length the nummulitic limestone occupies the highest ground, forming open, easy curves dipping from a nearly straight but broken scarp in southerly directions, where it becomes overlaid by the lower tertiary sandstones or Murree beds. These latter form two synclinal troughs, meeting endways on the high ground, and at one spot turning over somewhat as a horizontal cap covering the highest part of the ridge to the south.

The regularity of the beautiful curves formed by these sandstone outcrops is but slightly disturbed at a place near the Indus termination of the southern ridge where the beds in the opening of the widest trough, eastward, form one

Fine example of curvature of strata.



A Limestone B Sandstone and Clay C Debris D Fault

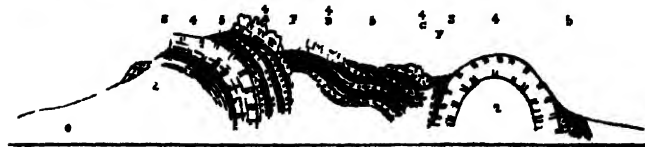


Fig 15 Section N of Kurovorum



Fig 16 Section from Suroomys to Southwards

contortion within another. The axes of both these synclinals coincide with the fall of the valleys, each bed curving round within another, one side of each trough conforming to the continuation of the ridge from Ismaíl Khéí, the opposite one to the southern slopes of the adjacent mountain.

At both the Turwábeyrá (Turwábérá) and Drubbokus ends of the latter long anticlinals may be traced, over the
 Anticlinal termination of mountain. axes of which these sandstone and clay beds roll into the rocky valley between these places and the Sireemeyla (Síríméla) hills, but along and beneath the escarpment of the limestone between these villages the sandstones are all vertical or dip southward as though to pass below the limestone which they are elsewhere seen to cover.

Among these lower tertiary sandstones, fossil bones or bone frag-
 Fossil bones, and wood. ments may be found, and in the deep valley between Weejoosum (Wijúsum) and Drubbokus one greenish sandstone zone at least abounds with exogenous fossil-wood.

From inspection of the map it will be seen that the ridges so far des-
 Deviation from east and west course. cribed have no absolutely fixed direction, but preserve their east and west course by gently deviating lines. Towards the localities last noticed there is a tendency to bend to the northward of east, an inclination which is further developed in the hills of the Sireemeyla (Síríméla) group.

These hills, like those which have been lately described, are narrow
 Sireemeyla (Síríméla) ridges, formed of, or at least covered on one side
 hills. by, the nummulitic limestone. The whole group rises more than might be expected, from the Kohát plains, but part of the apparent elevation may be caused by a sudden descent to the Indus, close to which they lie, and near which the ground is often rocky, rough and difficult.

The gypsum appears as usual either within an incomplete antio-
 Place of the gypsum. nal fold or on the sides of the ridges opposite to those which are covered with the nummulitic

limestone, and the tertiary sandstones generally, have strongly the Murrec aspect, purple sandstones alternating with bands of red clay. Over these the beds assume a greenish tinge, gray and greenish sandstones alternating with the usual reddish clays. One mass of these

Tertiary sandstones forming serrated outlines. beds on the northern side of the ridge from Sireemeyla eastwards, steeply sloping and with serrated outline, repeats in miniature much of the aspect of the beds facing the high Sheenghur (Shínghur) mountains as seen from this district.

The whole of these hills bear evidence of intense pressure, throwing the rocks into many sharp folds, the axes of which (as is often the case) maintain a certain horizontality for many miles, and then suddenly stooping below the level of the flatter ground disappear from view. The hills are also not more free from faults than elsewhere, the chief effect of which is to cause the total absence, sometimes for long distances, of the nummulitic limestone on one side or the other of the main ridges.

The narrow isolated limestone ridge of Wirshund north of Malgheen (Málgín) has suffered such disturbance that the same limestone rocks which form a compressed anticlinal to the east are perfectly vertical along its crest and continue so to its western termination.

The general arrangement of the rocks will be understood from the section in Fig. 15, crossing the Sireemeyla (Síríméla) ridge, the Drubokus valley, and the mountains to the south.

2. Gypsum. 3. Red sone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c. 5. Upper ditto.

Within a mile to the south-eastward of Sireemeyla (Síríméla) occurs the last known exposure of rock-salt in this direction, (it will be found described in the appendix). The salt occurs as usual closely associated with gypsum, a long and narrow stripe of which runs from beyond this place towards Weejoosum (Wíjúsúm), forming the core of the limestone hills,

(202)

and bordered by the red clay zone, which constantly underlies this limestone. Just at the place where the salt occurs there is a deep narrow valley leading the drainage to the Indus, and finding its way (as is frequently the case) right across the most southerly of the Sireemeyla (Síríméla) ridges. This valley is occupied by vertical or highly inclined

purple Murree beds, from which one walks directly
Fault. on to the gypsum, the junction being effected by a

fault in which at a little distance to the eastward a fragment of the limestone remains wedged as if to show that but for this dislocation it would have been continuous.

At the Weejoosum (Wíjúsum) end of this ridge the anticlinal structure is somewhat seen, but more strongly pronounced in the sandstone rocks, which, curving round, embrace its termination between that village and Chushum Bándá. Along the south side of the ridge the nummulitic limestone with many contortions shows itself always on high ground as far as the gorge by which the stream from Sireemeyla (Síríméla) escapes southward; but here changes sides, lying upon the northern slopes hence to its eastern end.

Close by the village last named another ridge commences, having the limestone also on its northern side, and the usual talus or débris covered slope to the south.

Near the eastern end of this are the sulphur pits of Gunjully, in alum shales just at, or slightly beyond, the border of the sulphur pits, Gunjully. map, but deserving of mention here, the place having the reputation of being formerly worked to a considerable extent.*

* The place is wrongly shown upon the map at the northern base instead of the southern side of the crest of the ridge, the error being one of from a mile to two miles. Prismatic compass bearings to fix it made Sookawur (Súkawur) Húkaní summit south 30° west, the summit of the mountain between Drubbokus and Turwábeyrá (Turwábérá) south $88\frac{1}{2}^{\circ}$ west, and the junction of the Teeree (Tíri) Tauí with the Indus south 8° east. The locality is referred to by Dr. Fleming (see Report As. Soc. JI., Beng., 1853, p. 346) as having produced 1,000 Lahori maunds of sulphur annually, but it is not now worked, though the sulphur might be made available for the blasting powder factory at Láchí, only twenty-four miles distant.

These black alum shales or sulphurous beds are situated close to the top of the gypsum apparently, but within it and not far below the nummulitic escarpment forming the crest of the ridge overlooking Gunjully. The whole of the associated beds are here intensely disturbed and thrown into sharp contortions, while immediately to the south a reversed fault makes the tertiary sandstone and clays at their junction with the massive white gypsum appear to dip beneath the latter.

The shales are in places very carbonaceous-looking, and on their weathered surfaces plates of selenite are lying, which have been apparently weathered out from them. Chemical reactions seem to be actively going on, the whole place emits sulphurous fumes, the pyrites in the shales is mostly decomposed, and the alum on surfaces of the rock acts strongly on one's hands. Native sulphur occurs on the sides of small cracks in the shale, small portions of which were easily ignited by a lens.

3. *The Nummulitic ellipsoid from Manzullí to Bánda on the Kohát and Bánnú road, &c.*

On ascending the Manzullí or Threekanushpa (Thríkanushpa) ridge near Rágo-tungí Síř, the Dullun valley, or plain, at the head of one of the branches of the Teeres Towey (Tíří Tauř) river is seen stretching away on the north side of the ridge to the Koorum (Kúram) river. In this valley there is not much rock seen, but what there is within view forms a continuation of the tertiary sandstones and clays of the Teeree (Tíří) valley. Rising from the latter between the two southerly head-waters of the Teeres Towey (Tíří Tauř) is the long anticlinal ridge of nummulitic limestone, round the nearest or Dumbáro end of which the sandstones are seen to bend northward from the village of Amán Kôt. This ridge, as far as it can be seen, appears formed of the same limestone, with the sandstones on its flank, forming the northern side of the Dullun plain.

Southward from the Threekanushpa (Thríkanushpa) (on the map Turkainushbo) ridge extends part of the country of the Wazírís, formed of a central somewhat elevated mass of soft undulating sandstones, supporting the crags of Káffir Kôt, a rocky depression intervening between this mass of sandstones and the point of view occupied by the lower beds of the tertiary sandstone series.

Between the Wuzírí (Wazírí) country and the Dullun valley the Manzullí range has a triple structure, each of the three parallel ridges having a limestone crest. Of these the most northerly is the inverted north side of the Manzullí and Bánda ellipse; the middle one corresponds to the southern side of the same, and the other is a narrow separate anticlinal divided from the rest by the overlying sandstones and clays. This anticlinal seems to have been broken through or eroded so as to expose some of the underlying gypseous clays. The place is, however, inaccessible, being within the

Wuzeeri country. The middle ridge of this western part of the range is also the highest, and here forms the boundary of British India. Its southern side is covered by contorted tertiary sandstones, clays, &c., of the Murree group, but in the valley to the north, the green clays (*Sheenkoura*) of the gypseous series, and the overlying red clay zone, occupy the space between the opposite limestone sides of what was once an anticlinal curve, the gypsum itself not being seen.

Just at the top of the ridge, and nearly due south of the village of Goorgoori (*Gúrgúrí*), the contortion is extreme, the nummulitic limestone being bent into such a curve as that shown in Fig. 16, (3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstones.) And apparently faulted against the flanking portion of the tertiary sandstone series. Caps of the latter rocks occur in more places than one, resting upon the limestone, and at the base of that shown in the sketch, the junction of the sandstone and limestone is effected by a passage bed in which lumpy nodules of the limestone, the size of one's fist and under, are enclosed in a sandstone base. These nodules become more numerous downwards, and within a few inches or a foot, the sandy matrix disappears, the upper layer of the limestone being a lumpy bed formed of the same nodules as occur immediately above. Besides this evidence of transition, there is in the nummulitic limestone here a single bed of greenish sandstone precisely resembling that of the tertiary sandstone series; it is 15 feet thick where measured, and intercalated between the limestone beds.

The valley between this place and the southern of the three ridges is occupied by closely contorted sandstones and clays, some of the gray sandstones near the mouth of this valley containing conglomeratic layers, (noticed at the ascent on the road south of Lachee (*Láchi*) as an unusual occurrence). Further south into the lower ground about Bahádur Khél contortions are still found for

three miles from the hills, the gray sandstones becoming soft and alternating with darkish-gray and brown clay as the Kaffír Kót mass of sandstones is reached.

Eastward of the Rágo-tungí and Turkainushbo Sírs* the sides of the:

Anticlinal eastward of Rágo-tungí. anticlinal separate; it is flanked by two smaller anticlinal folds, one on each side, both of which expose the nummulitic limestone: indeed, that to the south also shows in a deep ravine some of the immediately subjacent beds.

In this country greenish sandstones in thick or thin groups are not uncommon among the lowest or more decidedly purple tinged portion of the tertiary sandstone series. A strong zone of these flanks the southern side of the range north of Bahádur Khél, giving its side a distinctly green tint. This results very much from the position of the rocks, large portions of their surfaces being presented to the plain or valley, while the intervening clays stripped from these by erosion are hidden in small depressions, their concealment being no doubt largely assisted by the numerous arches into which the beds have been thrown.

The limestone zone of the southern side of the hills is everywhere intensely disturbed, often vertical, and sometimes bending over to the north, as though to rejoin that of the opposite side of the ellipsoid; just below it the usual red clays are sometimes visible, but more frequently concealed by nummulitic débris. Here, too, closely associated with the red clays of the red zone are disturbed masses of the brownish sandstones and gray clays or shales seen north of Murdán Khél and on Swánai Síir Mountains, while in the centre of the range even forming some of its highest ground at the Manzullí *boorj* or *chowki* the gypsum appears strongly in great masses alternating with gray or greenish gypseous *Sheenkoura* clays. The rock-salt

* Called by the natives Raothungi and Threekanushpa.

Salt localities.

is obscurely seen in a few spots mentioned in the appendix as the Manzulkí localities. The sketch section given in Fig. 17 crossing the range south-west of Amán Kót will convey a better idea of the state of things than any elaborate description. The range is here about two miles broad.

1. Rock-salt (place of). 2. Gypsum and clay. 3. Gray clays, brown sandstones and thin limestone layers, nummulitic. 4. Red clay zone. 5. Place of ditto. 6. Nummulitic, lumpy, and *alveolate* limestone. 7. Lower tertiary sandstones and clays, the very lowest of the former, in places conglomeratic. F.F. Faults.

The general obliquity of this section would suggest that the contorting north and south pressure was transmitted through the rocks at a considerable depth from the then surface of the ground towards which the opposing resistance proved strong enough to cause an underthrow of the whole section towards the south.

The region of this disturbance may have been considerably more deeply seated than the present place of the contortions when it is remembered that hundreds or even thousands of feet of upper tertiary sandstones and clays may have once reposed above the highest beds of the range.

The disturbance, though great, seems not to have been limited to the ordinary anticlinal and synclinal curves, but dislocation also, as one result of tension, apparently took place. In the centre of the main fold of the ridge where the rocks might be supposed to have had least room for alteration or motion, a certain disparity of the bed of the gypseous series and those close above the latter on each side of the axis may be observed (similar in a general way to that noticed regarding the sections north of Ismaíl Khél), so that both sides of the anticlinal within the hard nummulitic limestone are not close counterparts of each other. It may be supposed that the curve of the beds now incomplete was sufficiently extended to have admitted of some lateral changes during deposition, sandstones and clays predominating at



Fig 16 Curve in Nummulitic Limestone near Rajahmundry



Fig 20 sketch of Fault (Producing depression of a continued) Water fall Cause of Mytilus

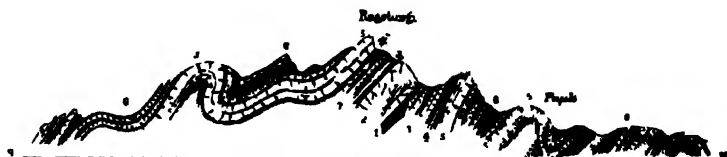


Fig 17 Section across hill SW of Amarakant Range here about 2 Miles long



Fig 18 Section across hills SW of Marki



Fig 19 Outcrop of Nummulitic beds near Surtung



Fig 22 Junction of limestone and Tertiary Sandstone Meramb Railway



Fig 21 Section at (Surtung) Salt locality W by S from Tim

one side over the gypsum and limestones and clays at the other. In a sharp curve like this, the sides of which are pressed into parallelism, whole groups of layers might have been squeezed out of their places in the curve. Something may be attributed to the existence of the salt, strong traces of which are present, and the removal of which by solution could well be supposed to have initiated lines of weakness, inducing displacement quite irrespective of any kind or amount of contortion which might have occurred.

In approaching the region of this section from the north or south, any ravine from the hills might show a local difference; along the line taken the lower tertiary sandstones and clays appeared at the north side as above, while other contortions off the line could also be seen, one of them coinciding with the conspicuous northern limestone arch.

Among the gray sandstones and red clays, close to these northern exposures of the limestone, are a few beds of calcareous pseudo-conglomerate, containing fragments, nodules, or pebbles of a rock exactly like the adjacent limestone, but showing no signs of unconformity.

Limestone pebbles in lower sandstone of tertiary sandstone group.

The limestone is whitish and lumpy, of the *Alveolina* kind, and seems to include a small lenticular mass of red clays. This limestone zone where the usual 'bad step' caused by it occurs a little further south, does not seem to be more than from 50 to 70 feet thick, and owing to the inversion has the appearance of being overlaid by gray clays and sandstones with some purplish bands, amongst which are limestone layers containing nummulitic fossils.

Inversion.

Southward of these are gray clays close to the few and small exposures of the rock-salt seen hereabouts. These are presumably faulted against masses of white amorphous gypsum.

Overlying this gypsum in proper order, gray clays occur again, the red zone usually occupying this position being apparently dispersed among the gray series, with some representative bands above near the base of the overlying limestone. Over the gray clays are several feet of light brownish sandstones rarely conglomeratic, and quite similar to that of Sháh mountains (Swánaí Sí). The immediately succeeding *Alveolina* limestone does not always form the very crest of the ridge. It projects at Rágo-tungí peak, but close by to the east sinks into the face of the northern cliff, leaving the succeeding sandstones (here containing a few small pebbles) to form the ridge.

From the crest southwards the ridge exhibits much folding and contortion of the limestone and sandstone beds, the red clay zone being seen in its proper place apparently, just within a large anticlinal curve of the limestone.

A mile or so to the eastward of this section where the path to the Manzullí Chowkí runs, the southern side of the anticlinal is inverted, the nummulitic limestone being again overlaid by the gray argillaceous beds, and purple sandstones and red clays intervening between these and the gypsum, but at a short distance further east, at the Thódrung salt locality, the series regains its natural order, bending from the south over the ridge into a long central glen of the range.

A little rock-salt is here seen under a cliff of gypsum much over 100 feet in height, above which comes débris of greenish clay for nearly 200 feet more, then red clays obscurely seen, and then the nummulitic limestone on the crest of the ridge covered by a thin cap of the tertiary sandstones.

The next section to be noticed crosses the ellipsoid near the meridian 71° east, the rocks being very much the same, but the contortion seems here even surpassed

by dislocation. Fig. 18 shows this section across the hills south-west of Sharkí near longitude 71° east, about three miles in length.

1. Rock-salt. 2. Gypsum and greenish or gray clays. 3. Gray clays. 4. Light brown sandstone and débris. R. Red clays. 5. Nummulitic limestones (lower?). 5a. Nummulitic sandstones, limestones, and gray clays, limestone layers containing *Alocolina*, &c. Some purple clays and sandstones. 5b. Purple sandstone and red clay (very like No. 7). 6. Hard nummulitic limestone. 7. Tertiary sandstone series. F. Faults.

The principal points in this section are the absence of the two lateral anticlinals seen in the east, the limestone not reaching the surface, the development in the lower part of the nummulitic group of limestone and sandstone bands, the former fossiliferous and the brownish sandstones of this horizon, being limited as before to the south side of the principal anticlinal axis, near which and near the little rock-salt seen the section again appears to be faulted. The absence of the red clay zone elsewhere so persistent in its place at the top of the gypsum (unless cancelled) appears strange, while it is found on the inner side of the nummulitic limestone to the south. Another peculiarity is the apparent intercalation in the nummulitic limestone of a zone quite resembling the overlying lower tertiary sandstones, and the occurrence of a mass of the two latter groups faulted into the gypsum area and apparently structurally different as to details from the nummulitic border on either side of the ellipsoid.

Approaching this section likewise from the north, the tertiary sandstones and clays are found much disturbed and vertical in the Tíri valley: towards the hills they assume open curves, and at foot of these a red clay zone is conspicuous among them. In a ravine up which the road led they become nearly vertical, again consisting largely of gray sandstones inclined at high angles to the west of south. The nummulitic limestone has the same somewhat inverted dip, changing to vertical, and a thickness of about 160 feet where the usual hard band crosses the gorge, forming one of the difficult little

passes common along the limestone zone. Above this apparently, but really of older age, come the following, arranged in their natural order from the limestone of the gorge downwards, as seen in the stream bank:—

Detailed list of beds at 5a in Section above lower nummulitic series, bedding vertical to south-west at 70°-80°.

	Feet.
15. Greenish clay and earthy limestone in thin bands overlying a layer of oyster fragments	5

Interval of 50 yards, probably soft beds.

14. Purple sandstones	2
13. Gray clay	} 80
12. Sandstone layer	
11. Gray clays	
10. Purple clay	
9. Purplish and gray clay alternating with layers of sparkling sandstone	
8. Earthy, calcareous, sandy <i>Alveolina</i> bed	} 12
7. Sandstone and gray clay alternating	
6. Gray clay	
5. Greenish-gray, lumpy, impure nummulitic limestone	20
4. Greenish, gypseous clay faulted.	
3. Mass of crushed green clay and shales, with hard, flaggy, lumpy bands, the latter full of Nummulites. All much contorted, any clear dips to south-west, exposure 150 yards.	
1. Oblique fault and place of rock-salt.	
2. Gray, smooth, and gypseous clays alternating with masses and laminated bands of gray and white gypsum.	

These latter beds, (the gypseous series), are pushed over, or obliquely faulted, so as to overlie the beds No. 3, and at the Displacement. junction the small salt exposure of Zawa-drung occurs.

Greenish clays next to salt.

The rock-salt here is immediately covered by greenish clays, over which a portion of the gypsum is seen.

The whole of the gypsum exposure here is much disturbed, undulating gray clays being among the lowest beds seen.
 Disturbance in gypsum.

These clays present strong interstratifications with the gypsum, but much of the latter gives no sign of its arrangement, though, on the whole, there appears to be a tendency among the undulations of the mass to dip in a southerly direction.

The Tírf and Bahádur Khél valleys in this vicinity, respectively north and south of the range, are open, the former particularly presenting numerous detrital terrace-like scarped hills. Notwithstanding these detrital accumulations, and probably resultant from the action which scarped them, there are numerous exposures of the rocks below, either in stream valleys or projecting reef-like through the surface, the angles of inclination of their strata being frequently smaller at some distance from than close up to the hill ranges or on their flanks. In the Tírf valley the beds have, on the whole, rather an older aspect than to the south in the Bahádur Khél country, towards the centre of which valley pebbly beds and their débris are sometimes met with. As a whole, the beds of both valleys may be described as a great accumulation of gray sandstones and red clays, the sandstones becoming harder and often of a purple tinge, below, near the nummulitic limestones. In the latter situation they

often contain somewhat indefinite small and fragmentary plant remains, while occasional pieces of fossil bones may be met with almost anywhere.

Plants and fossil bones.

Soorthung or Soortung Sír (Súrtung) is the name of one of the most lofty peaks in the country ($4,329 + 70 = 4,399$ feet), and certainly the highest on this range.
 Interior of ellipsoid near Soorthung (Súrtung) Sír.

In the broken lower ground forming the interior of the ellipsoid near it, one of the summits is formed by another detached group of the nummulitic rocks faulted into its present position, and occurring as an isolated patch upon the gypsum series. In this

patch and to the eastward the sections again differ from those above described; one or more thick bands of gypsum occurring in the basal part of the nummulitic series; and a 20-foot bed of this gypsum being seen to thin away to nothing within a short space in the scarped out crop along the northern side of the patch itself.

Fig. 19 shows the outlier of nummulitic beds near Soortung (Súrtung). 7. Brownish sandstones. 6. Soft beds. 5. White limestones. 4. Gypsum thinning out. 3. Whitish limestone. 2. Greenish clay in talus. 1. Gypsum.

Just to the north of the gypsum (No. 1 above) brown sandstones and shales appear on the inner slopes of the northern limestone rib at 7¹ so that there would seem to have been considerable disturbance and faulting at this place.

The red clay zone so intimately and constantly associated with the upper boundary of the main gypsum mass does not appear in its place, but there is a band of red clays at R. between the brown sandy beds and clays at 7¹ and the nummulitic limestone L.

The whole of the sections in the neighbourhood seem to be less constant or more irregular than usual, as if the different groups admitted of other bands of the same character as the neighbouring ones, and probably formed under recurrence of the same conditions, being included among them. Thus gypsum layers are seen interposed between limestones and red clay, and sandstones of a purplish colour occur also among the lower layers of the nummulitic series.

The faulting and disturbance of this part of the range are as prominent as usual. The high summit of Soortung (Súrtung) is formed of the tertiary sandstones

sloping slightly to the northwards, and faulted against vertical nummulitic limestones, between which and adjacent gypsum traces of Gypsum and other rocks. a red clay band were seen. This gypsum is again

faulted against the south side of the outlier. (Fig. 19). Associated obscurely with the gypsum are the usual gray and greenish shales and thick clays, with flaggy beds crowded with nummulites, towards the northern limestone, which, together with the clays, has a high inverted dip to the southward, and in a deep ravine crossing this limestone at a waterfall south of Maylookilla (Mélúkílla) red clays are again seen between the nummulitic limestone and

Quasi-contortion. nummulitic clays. Here, too, the limestone is faulted, so as to resemble a deep synclinal curve as shown in the sketch. Fig. 20. Sketch at water-fall south of Maylookilla (Mélúkílla).

a. Greenish clays and calcareous bands. b. Crushed red clay. c. Nummulitic, shaly limestones. d. Solid nummulitic limestone (4). e. Tertiary sandstones (5) much concealed by debris. f. Strong nummulitic limestones (4) g. Tertiary sandstones (5). h. Red clay.

Unless the limestone *f* be an entirely accidental and different band from that at *d* (which could not be proved), there must be here a faulted displacement in a vertical direction of very much greater amount than the distance between the two limestone ribs, which would admit of about 300 feet of the tertiary sandstones, &c., intervening. These latter are inverted, and the clue which they might give to the arrangement of the whole is lost in consequence of their being much concealed by debris. The occurrence of the red clay at *b* may indicate another parallel fault, and a pocket of very similar red clays at the foot of the waterfall at *h*, close to the nummulitic limestone, is too obscurely seen to admit of its being referred decisively to either the tertiary sandstone series or the supra-gypseous red zone.

A couple of miles eastward of Soortung (Súrtung) in the neighbourhood of the rock-salt locality of that name, complexities also exist, faulting and disturbance

Complexities at Soor-
thung salt locality.

rendering the arrangement obscure, still a tendency to an anticlinal structure may be observed. The clays of the gypseous series appear to be locally very thick, though much wasted, and the gypsum is most largely developed on the south side of the original curve or arch. Fig. 21 shows this section at Soortung (Súrtung) salt locality west by south from Teeree (Tírf).

1. Salt. 2. Greenish and gray clays. 3. Thick gypsum bands. 4. Brown sandstones and earthy limestones and shales with bands of gypsum and of purple or red clay. 5. Shaly and compact nummulitic limestones. 6. Tertiary sandstones, clays, &c. Three feet red clay bands to south of section. B. Thin red clay north of section. G. Thin band of gypsum. F.F.F. Apparent faults.

Ascending to the first northern brow of the range here, over curved and tilted tertiary sandstone, some thin, shaly, and nummulitic limestone associated with gypsum. harder limestone of the nummulitic series crops out along the summit of the ridge, and turning over faces its southern side, sloping into the valley. Just at the northern outcrop at one spot, a little gypsum was found beneath the limestone, and as if overlying some red clay. Towards the top of the outcrop very Lower Nummulitics. dolomitic-looking limestone, succeeded apparently the more shaly kind, and then overlying this with a dip of 30° to the south came a glistening saccharoid gray sandstone succeeded by red clay and purple sandstones, then by sandy clay with masses of white, opaque, gypsum in it, all over laid by 80 or 100 feet of dull, earthy, calcareous and sandy rock, passing in places into hard, whitish and gray calcareous sandstone, coarse calcareous sandstone and limestone in places.

These rocks soon change from their southerly dip, forming a synclinal curve as shown at 4 in the section, but in the southern outcrop of this synclinal the section is not at all the same as that to the north.

The calcareous and sandy rocks last mentioned form the upper edge of this scarp, resting upon 50 feet of whitish, soft, Gypsum in this group. -gypsum, beneath which is a talus of 200 feet or so chiefly formed of greenish-gray clays.

There seem to be different beds of gypsum among the sandstones of this escarpment, one evidently subsided portion of the hill exposing the following succession :—

				Feet.
5.—Light coloured clays	...	..	...
4.—Gypsum	...	...	..	6
3.—Calcareous sandstone	...	.	...	8
2.—Sandstones and clays	...	...	..	50
1.—Greenish clays	...	...	...	70

Mere faulting along the face of the nummulitic limestone at the northern side of the section appears insufficient to account for the relations here, and yet the occurrence of these gypsum bands close to the limestone and among the sandy and earthy beds, elsewhere below it, together with the occurrence of nummulitic layers in the greenish clays down in the khud immediately to the west, would seem to point strongly to the important fact of the limestone and gypsum series both forming parts of the same nummulitic group.

Limestone and gypsum both belonging to one group.

The ground about the salt sepoys' (sipáhis) boorj or chowkí at the foot of the escarpment just now described is all of clay, clay debris, and fragments of the local rocks, some deep circular openings at the heads of streams running to the eastward, exposing from 50 to 70 feet of this heading over the gray rock-salt which was from appearances estimated to have a depth of 100 feet, and an uncertain dip to the west and north-west.

Salt locality.

A high tabular hill to the eastward overlooking the salt locality and salt chowkí shows the sandstones and purple or red clays of the synclinal north of the chowkí forming a nearly horizontal cap to the hill, the lower slopes of which are composed chiefly of the clays beneath.

Cap of the lower nummulitic series.

To the southward of the chowkí a long rib of gypsum stretches in the direction of the range, traces of red clay occurring both along its northern and southern sides, the former between it and the clays associated

Gypsum and limestone of the southern side of range. Inversion.

with the salt, the latter intervening between the gypsum rib and the nummulitic limestone of the southern side of the ellipsoid which, like that to the north, is inclined the wrong way, dipping to the north, or is vertical or disturbed along the inner side of the southern ridge, the outer slopes of this being formed, generally up to the crest, by the lower beds of the tertiary sandstone and clay series.

To the east of this Soortung (Súrtung) salt locality for about three miles the ridges forming the opposite sides of the ellipsoid diverge, leaving a wide space between covered with gypsum and débris of the accompanying clays, the nummulitic limestones as usual forming the crests of the outer ridges, or reaching high up on their inner sides, and traces of the usual red clay zone being observable between the limestone and the gypsum within.

Where the Merándí (Mírándí) short cut or bridle-path from Teeree (Tíri) to Totukhí crosses the range, the true relations of the rocks begin to become more apparent. The lower tertiary sandstones and clays at a short distance south of the Teeree (Tíri) river dip northward at high angles up to 60°. Further southward up the ascent they become contorted, and are at last faulted against the nummulitic limestone, having patches resting upon it, and the junction with the limestone here at one spot presenting the appearance seen in Fig. 22, which shews the junction of limestone and tertiary sandstone, Merándí pathway.

1. Contorted purplish-gray sandstones and purple clays. 2. Contorted and crushed nummulitic limestone.

Where the path gains the first summit, the nummulitic limestone and shales are seen to form an irregular and disturbed band undulating along the crest, sending out a short narrow projection among the sandstones to the north-east, while to the eastward they pass gently and conformably beneath the latter rocks. A few paces southward near a small tank the limestones are much disturbed, and a few beds

of the sandstones are brought in by faults, the little tank itself being upon the bright-red clays usually found just beneath the nummulitic limestone. A rising ground above the path here exhibits interstratifications of the gypsum and sparkling gray sand-

Gypsum and sandstone of lower nummulitics again interstratified.

stones of the interior hills undulating over the ground, the gypsum, as usual, being apparently thin at its northern exposures and more largely developed towards the southern side of the ellipsoid. Proceeding still to the southward over this undulating gypseous and sandstone series the red clays are again met with at the foot of a long east and west escarpment rising above all the neighbouring hills, formed mainly of the hard

Alveolina limestone.

alveolina and nummulitic limestone dipping at low angles and forming a bold curve as it descends to the southward, quite conformably overlaid by the tertiary sandstones and clays.

This outcrop of the limestone turns pretty sharply to the south, exposing a fine section, where it overlooks the gypsum towards the southern side of the exposure of the interior of the range, the gypsum being here much more developed and deeply cut through, sometimes leaving natural bridges over the mountain stream close to the path. Gray clays are also here associated with it, but though the stratification is in places plainly seen the general relations are obscure, and the ground is much covered with gypseous debris.

The section in the portion of the limestone escarpment presented to the westward shows the following succession:—

	Natural order, beds dipping south at low angles.	Feet.
Tertiary sandstones, {	8. Purple sandstone, tertiary sandstone series ...	60
'Murree beds' ... {	7. Deep purple sandstone and reddish purple clays do. ...	
	6. Hard <i>alveolina</i> limestone ...	15
	5. Thin, flaggy, limestone and clay ...	35
	4. Greenish clay ...	20
Nummulitic ... {	3. Dark-gray limestone ...	5
	2. Green clay with layers of sandstone ...	20
	1. Deep and bright-red clay, with some flaggy, harder bands containing nummulites, &c.: thickness not seen, but 50 to 100 feet exposed in the vicinity.	

Fig. 23 shows this section near the Merándí path from Teeree (Tírf) to Totukhí, about three miles.

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone and clay. F. Fault.

The red clay zone, as seen at the southern part of this section, contains some hard gray sandstone layers and earthy nummulitic bands in the red zone. calcareous bands with *nummulites* and other fossils, these layers being sometimes ripple-marked; some purple flaggy beds also occur, and layers of this red clay and of gypsum alternate near the junction of the two groups as if to unite the gypseous series with the overlying nummulitic rocks.

The whole section so steadily and plainly exposed beneath the tertiary sandstone capping the limestone in the Sharp inversion. above section becomes sharply reversed to the southwards near where the Merándí pathway issues through a narrow gorge cut in the nummulitic limestone, here pushed over so as to incline to the northward at 50°.

On the east side of the pathway before it leaves the gypsum, which is in this neighbourhood intensely contorted, and Salt locality. in the middle of a bank of gypseous rubble, there is a small exposure of rock-salt purposely concealed in the left bank of the stream which makes its exit through the gorge just mentioned, and which near the place leaves upon the stones in its bed a thick incrustation of salt.

South of the Little Pass, the tertiary sandstones at first dip northwards with the limestone, being very calcareous for Tertiary sandstones, &c. 4 or 5 feet at the junction, but further out are inclined both ways at high angles towards a synclinal axis; another synclinal occurs further on, and between the two a fine anticlinal curve is seen in the adjacent spur to the west.

At a little distance from the hills, the purple sandstones and red clays resting upon the limestone high up on the hills, as shown in the

section, may be traced curving round the crushed and inverted fold in this limestone and passing downwards so as to underlie it in the way represented.

The part of the Bahádur Khél valley near Totukhí lies high, separating the waters of the Teeree (Tírí) valley streams from those of the Kurshru Algud, and is rocky, the tertiary sandstones being set on edge with a high dip to the south where not vertical. The rocks are as usual gray sandstones and red clays of a higher place in the series than those nearer the hills, and showing less of red or purple colour, besides which the soft gray sandstones occasionally contain scattered pebbles of quartzite or conglomeratic strings.

Exactly to the south of the village of Teeree (Tírí), and to the south by east, the sections are very instructive as to the true relations of the rocks. The bold curves which these form may be seen from long distances on the northern flanks of the range, and on closer inspection the conformity of the groups at least down to the gypsum, which is generally more or less obscure, is as clear as their arrangement is in other places complex. The section seen is as shown in Fig. 24, the curves overarching a space of nearly a mile in breadth :—

2. Gypseous series. 3. Greenish clay. 4. Red clay zone. 5. Nummulitic limestone. 6. Tertiary sandstone, &c.

- 5 { 8. Gray and purple sandstones.
7. Reddish purple clays and sandstones with bone beds.
Clay bands numerous.

					Fect.
4 {	6.	<i>Alveolina</i> limestone	...	...	100
	5.	Shaly limestone	...	...	100
	4.	Greenish and whitish marly clays chiefly	...	...	50
	3.	Blood-red clays (thick here)	...	...	200 ?
	2.	Green clays (a few feet).			

1. Gypsum and clays, very thick, unknown amount in continuation of the sandstone and gypseous series, 1 in Figure.

By carrying this section southward over the hills, it would traverse the continuation of the limestone and overlying sandstone of the

southern part of the foregoing Merándi section, and the anticlinal character of the whole range would at once become apparent. Facts like these in the arrangement of the rocks are worth notice, both because of their rarity and their importance in fixing the true relations of the complicated appearances to be found so often among the rocks of the country.

The uppermost beds of the limestone are of the lumpy, hard *alveolina*-bearing kind so commonly found just at the junction with the tertiary sandstones, and the lowest beds of these at this place include besides a peculiar concretionary band, the nodules of which range about the size of walnuts and under, some pseudo-conglomeratic calcareous layers containing bones smooth, polished, fluted and pointed, reptilian teeth, crocodilian scutes, and tortoise plates abundantly, but in a fragmentary state.

The regular anticlinal just now noticed is not maintained for any distance eastwards, an instance to the contrary occurring southward of the village of Hossain Bándá at the Burburra boorj or salt chowki on the northern crest of the hills; here from the ridge a little to the westward the nummulitic limestones and the sandstones above them are again seen inverted as in Fig. 25.

3. Bed clay. 4. Nummulitic limestone, here only 50 feet. 5. Tertiary sandstone, &c.
A calcareous gravelly bed at the junction with the limestone.

This Burburra boorj overlooks to the southward one of the largest salt exposures in the country after that of Bahádur Khél. It is known as the Serappah or Burburra-drung. Here the whole of the interior space between the outer ridges of the range is evidently much disturbed from slippage and subsidence of the soft rocks; in consequence of the existence and removal of the salt beneath, great patches of gypsum extend over the ground, and gray and

Serappah or Burburra
salt locality.

greenish clays are, as usual, obscurely intercalated with it, this gypsum not being traceable with any continuity throughout the tract.

Towards the fringing nummulitic zone north and southwards red clays are strongly seen, and in one of the deep gullies opening to the south, under a mass of reddish coloured clay-débris, the dark rock-salt is horizontally exposed for nearly half a mile, chiefly towards the bottom of the ravine on both sides, but rising in the banks and side nallahs high up nearly to the general surface of the hilly ground. Its total thickness is nowhere visible, but must exceed 100, while it may be more than 200 feet.

At one spot towards the head of the stream, a little black gypsum and black shale appeared at the base of a salt cliff, but as this is usually the character of the gypsum just overlying the salt, or even higher up near the top of the gypsum itself, and as the place was much overrun with detritus, it would be unsafe to draw conclusions from an unsatisfactory exposure of the kind which might have slipped bodily from above, nor could any results be arrived at from the clay in contact with the salt now occupying a place which might easily have formerly been filled by gypsum or the gypseous series. Gypsum is seen in quantities approaching the spot from both sides, but near the ravines it greatly gives place to débris.

Notwithstanding the recurvature of the limestone to the north as shown in Fig. 25, this northern side of the section North side of section most regular. presents more of the original anticlinal arrangement than the succession to the south, the tertiary sandstones dipping steadily into the Teeree (Tíri) valley, while on the opposite side of the range these tertiary sandstones and the nummulitic limestones are either quite vertical or slightly inverted.

The next glen eastward from Serappah opens to the northward, and though only half a mile distant again exhibits Glen to east of Serappah. extreme complication, much faulting, and a locally large development of the red clay zone, while the great mass of salt

seen at Serappah is not exposed. The section seen when approaching from the north is as shown in Fig. 26.—

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone and clays.
F. Faults.

- | | |
|---|----------------|
| 5. Gray sandstones, purplish sandstones, and purplish-red clays, pseudo-conglomerates, purplish-gray clay at junction in one place, in another gray sandstone ... | part only. |
| 4. Hard <i>Alveolina</i> limestone ... | 20 to 50 feet. |
| 3. Red clay zone, largely developed at one place ... | 300 to 400 " |
| 2. Gypsum, stratified and unstratified, clays, &c., may be | 400 or 500 " |

Entering this mountain glen behind the village of Khurree (Khurrí)

Tertiary sandstones: Bánda the usual lower purplish and gray tertiary nummulitic limestones: sandstones form open undulations, and in one spot their contact conformable, but peculiar. a curvature in these allows the nummulitic limestone to be seen, taking the ground in all directions. Somewhat within the glen a continuation of this limestone (*a*) appears as if faulted on its northern side, a small surface of the limestone being exposed in the centre of an anticlinal curve. At the contact the limestone is lumpy with interstices filled by purplish-gray clay similar to that of the adjacent bed above; this is succeeded by gravelly layers containing concretions and pebbles of bluish limestone and of sandstones similar to those in the immediate vicinity, the sandstone and limestone beds being quite parallel and conformable.

For two or three hundred yards up the stream, the ordinary gray sandstones and purple clays of the lower tertiary sandstone are much crushed and contorted, and then the northern nummulitic rim of the ellipsoid (*b*) is reached. This limestone is of the hard *alveolina* kind, and is inverted, dipping south at 80°, the gray tertiary sandstone coming next above (but here underlying) it, having been apparently crushed along its surface in such a way that angular portions of the limestone were dragged from their places and gray sandstone forced into these cavities to a depth from the surface of the limestone which in one place measured 10 feet. The fractures of the limestone are all angular, and



Fig. 23. Section near Merandi path from Tiri to Totakhi

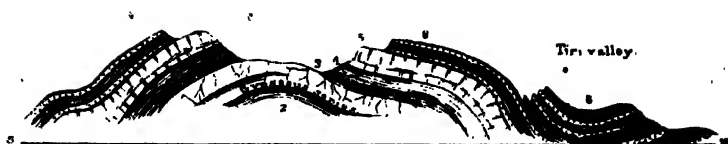


Fig. 24. Section Southward of Tiri Village

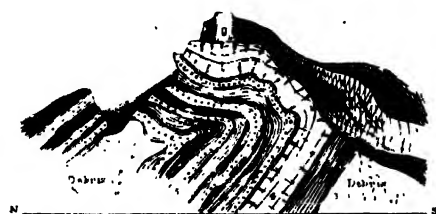


Fig. 25. Section at Burbura boory

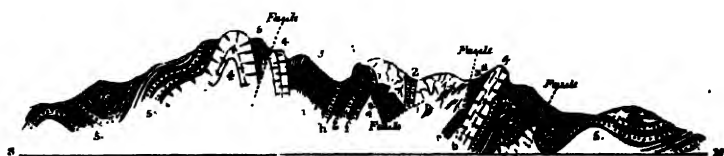


Fig. 26. Section east of Burbura Salt locality

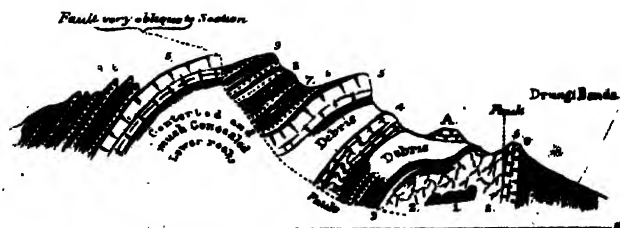


Fig. 27. Section behind Drung Banda

present no trace of erosion, nor are there any signs that the sandstone was deposited in these irregular hollows. The limestone here seems irregular, but thinner than in most other places, not being more than from 20 to 50 feet in thickness. On its inner side some greenish clays are in junction with it in the stream bed (c), but on the height above the left bank of this (d)

Red clay zone.

red clays occur in their natural place next to the limestone. Further up the stream, contorted and obscure masses of gypsum and greenish clay, the latter often wedged apparently among the former, are seen filling up the interior portion of the range. At one spot where the stream crosses a mass of the gypsum, the latter is so deeply eaten into that it becomes impracticable to keep to the river bed, and here a small

Faulted inlier of sandstone.

mass of the tertiary gray sandstones (e) and red clays appears to have slipped from somewhere above into the middle of the gypsum. Just beyond this to the southward the gypsum (f) is plainly stratified, vertical below, but bent over above as shown in the figure, and is in close contact with 35 feet of greenish clay (g), also vertical. Next beyond these in the same direction is a 5-foot band of hard gypsum (h), beyond which comes a mass of deep red clays

Junction of red clay and gypsum.

(i) with green and purple sandy layers or some-what flaggy bands, all on edge and dipping at high angles to the south, their thickness being estimated at not less than 350 feet. The surface formed of these rises towards the southern crest of the range where the nummulitic limestone again appears, but in contorted and broken exposures, among the tertiary sandstones and clays of this side of the ellipsoid.

From the high ground here eastward the range declines to its termination south of Bánda Serai on the Kohát road, the crest of the ridge being formed of the tertiary sandstones, while below it to the north the nummulitic limestones of both sides of the ellipsoid unite, forming a single anticlinal curve, somewhat broken and disturbed along its northern

Termination of range near Bánda Serai anticlinal.

side, but seen to take the ground nosing to the eastward and consecutively enfolded by the sandstone and clay series, where the Kohát and Bánnú old road has been abandoned for a better line curving round the end of the range close to the south bank of the Teeree (Tíri) Tauí river.

The whole of this range from Manzullí to Bánda, apparently in consequence of the large development of gypsum and soft rocks within the limestone-crested ridges, and the great pressure exerted upon them, presents some of the most complex ground in the district. From the details given, it will be seen that in many places it is difficult to conceive what forms eroded or denuded portions of the sections may have taken. It will be also evident that without the existence of the few sections in which the rocks are normally superposed south of Teeree (Tíri), and the evidence afforded by the anticlinal south of Bánda, or similar sections elsewhere, the task of reducing such a mass of contradictory confusion to anything like proper order would be well nigh hopeless.

4.—*The ridge from Bánda Serai to the Jatta ellipsoid.*

This ridge, which has between the points above named a summit elevation of 3,198 feet (the correction in the note upon the Trans-Indus Frontier map being added) is little less complicated than the more extended range just described.

The rocks are broken and displaced by faults, yet remnants of a former ellipsoid structure are to be recognised in the narrow and fragmentary bands of the nummulitic limestone along its southern or scarp side.

At the western end near Bánda Serai and military post, the nummulitic limestone which sheets its northern slopes may be seen making a half turn to come round and join that to the south, but the curve has hardly reached the axis of the anticlinal till it is suddenly interrupted apparently by a strike fault,

leaving the southern slopes open to expose the gypsum and other soft strata of the interior of the range, where these are not overrun by limestone and other débris from the outcrop.

Just above the road westward from the Serai some of the gypsum is seen, and some contorted liver-coloured thin sandstones forming part of the red clay zone. The latter, too, may be traced at intervals just below the outcrop of the limestone on the crest of the hill, this feature being formed by the hard yellowish *Alveolina* limestone or marble beds.

Within a mile to the east of the Serai some small exposures of the rock-salt occur among black, earthy gypsum and red clay, purple sandstone, and limestone débris, in the banks of streamlets on the southern side of the ridge, but the sections are so overrun and concealed that nothing of the structure is observable. Near this place narrow vertical exposures of the nummulitic limestone commence, and these continue more or less visible to beyond the village of Drungí Bándá at the foot of the ridge where the Teerec (Tíri) river makes a sharp S-like turn in its easterly course.

Salt quarries are said to have been formerly worked behind this village (hence its name), and on entering the little valley in which they are situated on the southern slopes of the ridge, purple, greenish and gray sandstones and purple clays are found perfectly vertical. Between these and the southern rib of *Alveolina* limestone, which is also quite vertical, is a zone of redder clays than usual among these rocks with gray sandstone layers interspersed. The limestone itself is thinner here than usual, the whole of the beds not being apparently present. Just

Drungí Bándá salt locality.
Limestone, thin: black gypsum: alum shale.

behind the limestone is a mass of gray and black gypsum and black bituminous alum shale, any stratification in which appears to undulate to the northwards. Low down in this gypseous mass, or more likely just below it, blackish-gray rock-salt is seen for a thickness of 10 or 15 feet on the left bank of the stream and close to its level. The salt appears

also to dip to the north at a low angle, and may very probably be but the upper portion of a thick deposit, as seen elsewhere. The black bitumi-

Bituminous shale and sulphurous springs. nous shales close by smell strongly of petroleum, and sulphurous springs issuing from them are saline and milky-looking, but leave a black deposit on the stream bed, contrasting strongly with the snow-white salt incrustation on the drier places.

Immediately north of the gypseous mass some red clays are seen, succeeded by variegated sandstones and nummulitic limestones having high and contorted dips to the north as follows:—

7. Red clay and green clay mass, all crushed and unconformably overlaid by a displaced mass of gypsum close to a large fault.

	<i>Fault.</i>					<i>Feet.</i>
6. Hard, cherty limestone and gray shales exposed with high and distorted dip to north for	100
5. Variegated yellow and purple sandstone	50
4. Coarse purple sandstone	
3. Red clay, small exposure.						
2. Black and gray gypsum, and bituminous shales				?
1. Rock-salt dark-gray and blackish, seen	15

The red and green clays No. 7 appear not to belong to the succession

seen here, but more probably represent some part of the infra-nummulitic limestone red clay zone. The

lower part of the limestone No. 5 has coarsely oolitic-looking portions made up of small foraminiferous-looking organisms, sometimes like tiny

Fossils of nummulitic limestone. *nummulites*. Above these long *turritella*-like shells

occur, and small spherical bodies covered with

punctures. In a gray shale band here, and in a limestone layer just above it, small *nummulites*, spiral shells, and fragments of bivalves occur.

Next above these, a dark compact thin oolitic-looking layer encloses fragments of oysters, and the uppermost layer of all is highly fossiliferous, containing many of the common *gastropodous* and *bivalve* shells of the nummulitic limestone. Tracing this zone up the hill side a considerable

interval covered with sloping detritus and probably occupied by soft beds

is seen, and then the stronger *alveolina* beds crop out forming the high summits of the ridge.

From the place of No. 6 in the above section a strong fault starts to the north-east by north obliquely across the ridge, throwing the limestone last mentioned to the southward, and introducing a mass of the tertiary sandstone series on the outcrop side of the continuation of the nummulitic limestone sheeting the northern side of the ridge. Fig. 27 gives the section behind Drungi Bánda.

Fault.

1. Rock-salt. 2. Gypseous series. 3. Clay and sandstones; (section given above). 4. Nummulitic limestone and shale. 5. Nummulitic *alveolina* limestone. 6. Red clay. 7. Purple and gray sandstone and clay. 8. Purple clay and dark-gray sandstone. 9. Gray sandstone and red clays. 6, 7, 8, 9. Tertiary sandstone series. F. Fault?

From this place eastwards to the junction of the ridge with the Jatta hills north of Zunuk the general arrangement of the rocks is the same as that of the southern part of the above section, except that the southern band of limestone is less regular, or ascends somewhat higher on the hills and caps one of them as at A in the foregoing figure.

Just before the ridge adjoins the Jatta hills, its crest alone is occupied by the limestone, which is slightly faulted in an east and west direction, the tertiary sandstone to the south rising high upon the ridge, and the lower purple and bone beds with shark's teeth, &c., of the same series entering as a synclinal curve the valley between this ridge and the western end of the Jatta ellipsoid.

The open ground northward of this ridge is less rocky than that to the south, where the banks of the Teece Towey (Tíri Tauí) and the ground above them both expose the gray and red vertical or inclined, alternating red clays and gray sandstones of the lower tertiary sandstone series.

5.—*The Nummulitic Ellipsoid of Jatta.*

This ridgy feature is connected with the range just now described, but evidently owes its origin to a different anticlinal axis. It is about seven miles in length by one in width, and its harder strata, though faulted both longitudinally and across the strike, have decidedly anticlinal terminations at either end of the feature. The softer gypsum and rock-salt forming the interior of the curve are largely exposed, but the outer rim of limestone is incomplete, having been cut out by a fault at the valley of the Ismaíl Khél river on the northern side of the ellipse.

Towards the southern side of this at both ends the superficial exposure of the nummulitic limestone is largest, but between these points this limestone is on edge, showing many signs of disturbance, or almost disappearing owing to dislocation.

The tertiary sandstones surrounding and enfolding the limestone are of the same character as those usually forming the lower part of this series. The red clay band just beneath the limestone does not appear to have the thickness it sometimes displays, but is seen in sundry places, and the gypsum below is of the common dull gray and white kinds passing

Black gypsum and alum shales. in places into very dark or a black bituminous rock, associated with which are alum shales.— Below all

the salt appears to conform to the general anticlinal structure; it is of the usual gray colour, but in certain localities near the top is sufficiently bituminous to smell strongly of petroleum, a scent which may also be perceived slightly in some of the apparently purest rock-salt of the quarries at Jatta.

Near the road from Ismaíl Khél to these quarries and the Ismaíl Khél river up to the slopes of the hills, softish, gray and purple sandstones and purple clays with some very red zones of the latter are, as a rule, nearly vertical, dipping one

way or the other a little from east and west lines of strike. A band of purple color runs along the side of the hills, and between this and the limestone the clays have a redder tinge.

In the gorge of a stream due north from the quarries, this red band underlies the nummulitic limestone at an angle of 70° , both being inverted. The limestone here is about 80 to 100 feet in thickness, and consists of *Alveolina* limestone outside, hard, dark, and flaggy limestone with one cherty band near the centre, and more shaly alternations with thin

Fossil shell sections in oyster-bearing bands towards the south or lower part of the group. In the hard dark limestone,

sections (presumably of long *gastropodous* shells) of the forms shown in Fig. 28 are not unfrequent, and have also been observed in other neighbouring parts of the district: the figures are about natural size. Just inside the limestone band, a considerable quantity of very red clay

Gypseous series within the limestone border, occurs, in which there are purple sandstone or flaggy layers; south of this clay and within the

belts formed by it and the limestone, the gypsum and gypseous clays cover the ground, being irregularly and unequally spread over it, sometimes in quantity though of uncertain thickness, and sometimes as close to the highest of the salt quarries, apparently absent, or but poorly re-

Section.

presented. A projecting part of the escarpment here presents the following section, but the upper

zones were not within reach of measurement:—

(Arrangement nearly horizontal).

5. Nummulitic limestone, a remnant.	Ft.
4. Red clay zone	25
3. Greenish clays (<i>Sheenkoura</i>)	6
2. Dark gray salt, bituminous for 2 feet at top ...	10
1. Good gray salt	50

Along with No. 3 at a little distance was a 10-foot band of greenish-gray gypsum.

To the northward of the salt chowki or boorj, on the rising ground there, covered with gypsum and gypseous debris, the former contains a black carbonaceous-looking

Black shale.

shaly layer 10 feet thick, not traceable far, and dipping south at 40° . It looks like alum shale, but has no bituminous or sulphurous smell.

The salt in these Jatta quarries seems disposed in a thick zone, par-
 taking of the general anticlinal structure of the
 . Rock-salt said to have been worked through. place and rising to the westward. In this the
 whole of the quarries might be situated within a thickness of from 200
 to 300 feet if the salt were extended horizontally. There are no means
 of estimating the true thickness of such a zone, but quarries at different
 elevations show a depth of 15 or 40 or 60 feet of solid salt. In one of
 these quarries, and that one of the lower ones, though not the lowest, the
 single case in the whole district of their having ever, even by repute, been
 penetrated came to notice. Here at the 'Thathara quarry' a '*Drungwal*'
 or quarryman stated that at one time long ago when the quarry face had
 not been worked back so far north, a bottom to the salt had been found,
 and that *Sheenkoura* (gray gypseous clay) occurred beneath. The
 statement, however, seemed doubtful, and even if true, an older working
 of the kind described in the appendix may only have been reached, and
 not the true base of the salt deposit, so that the workman's story may be
 taken with a considerable grain of the adjacent mineral.

The whole of the salt appears to take the ground to the eastward,
 and all the quarries and exposures occur within
 Salt taking ground to eastward. a less space than one mile in an east and west di-
 rection. At a short distance eastward, after passing the last quarry,
 there are seen what look like two old pits or excavations in some black
 alum shale overlaid by impure gypsum. The shale seemed to have
 become partially burnt spontaneously ; it contained iron pyrites, much
 iron oxide, and some coaly layers. One band in
 Salt, alum shale, and gypsum smelling of pe- the clay was crowded with small nummulitic
 troleum. shaped bodies composed of gypsum. The whole
 was disturbed, and the dip at one place shifted to the west of north
 at from 20° to 40° , the thickness exposed being about 15 feet. The

gypsum close by smelled strongly of petroleum, as did also some of the clearest salt far below the dark bituminous upper layer.

What may have been fragmentary portions of this or similar bands of dark carbonaceous-looking and bituminous clay were seen also in connexion with the salt of those quarries on the northern side of the ellipsoid. One of these overlying a corner of the Thathara quarry absolutely stank of petroleum, and in this and other quarries near it and further west cracks in the salt had been filled either with such bituminous clay or with a sandy deposit sometimes evidently washed in from above. Other fragmentary bands of alum or bituminous shale and petroleum-smelling gypsum occur to the eastward near where the Ismaíl Khél river crosses the ellipsoid to join the Tírí Tauí. The diffusion of petroleum through the salt and gypsum here is remarkable.

To the southward of the alum shale pits there is at one place much confusion close to confusion close to the southern rib of the limestone, red clay, greenish clays, gypsum, and the nummulitic limestone being jumbled together as if portions of the interior rocks had at one time slipped or been pushed outwards across the limestone. At a short distance, however, the series is seen nearly vertical, but in proper order, the tertiary sandstones outside, then about 50 or 60 feet of the nummulitic limestone, behind which are greenish clays or shales in contact with red clays thicker than the limestone, and containing purple sandstones. At the northern or lower side, the gypsum and gypseous débris of the interior adjoin the latter, and further relations are lost.

At that part of the ellipsoid where the northern rim of nummulitic limestone is cut out, and the Ismaíl Khél river enters the gypsum, the junction of the tertiary sandstones and the faulted limestone is peculiar.

Nummulitic limestone cut out by fault; and shells in tertiary lower sandstones.

Fig. 29 shows this nummulitic limestone under cut by faults above the left bank of Ismañl Khél river.

1. Gypsaceous series. 2, 3, 4. Nummulitic limestone. 5-14. Tertiary sandstone series.

Dip North 80° and less.

14. Gray and green sandstones with purplish clays.	
13. Purple sandstones and clays and pseudo-conglomerate.	
12. Purplish-gray sandstones with a few bands of very red clay.	Feet.
11. Dark purple sandstones	5
10. Red clay	10
9. Purple, flaggy sandstone with green blotches	2
8. Thin-bedded, gravelly-looking, purple pseudo-conglomeratic or conglomeratic beds, limestone concretions, and fragments of yellow limestone with nummulites, bone fragments in base, thin out	8
7. Hard, red, calcareous, flaggy shale	10

In this is a narrow 9-inch layer (6) of calcareous nature crowded with imperfect casts of strongly-ribbed *bivalve* shells resembling some kinds of *Cardium*, or *Cardita*, imperfectly preserved in white carbonate of lime; the only shells found in the tertiary sandstone series—

<i>Fault.</i>	<i>Feet.</i>
6. Compact <i>Alveolina</i> limestone wedging out of yellow or buff colour, fossils scarce	50
5. Thin-bedded white and yellow limestone with <i>Nummulites</i> , <i>Alveolina</i> , <i>Cardita</i> , and other bivalves	15
4. Gray, shaly, nummulitic limestone full of small <i>Nummulites</i> and in parts minute organisms giving the rock an oolitic look	20
Room for some feet of soft beds? Red clays not seen.	
2. Gray gypsum with dark or black large patches highly impregnated with petroleum or bitumen.	

The actual amount of underlay seen here bringing the vertical sandstones, &c., beneath the vertical limestone is very small, yet probably extends to the whole thickness of the limestone, 80 or 90 feet, as this is completely cut out, unless, indeed, there be another shift of the beds on the southern side of the limestone also where the red clays are not seen.

Advocates for entire unconformity between the limestone and next newer beds, which the structure of this country has never been found to support, would probably

Fault, not unconformity.

claim a case like this as corroborative of their view, and might do so with some reason, if a hollow only had here been excavated from the limestone surface, no other signs of disturbance affecting the neighbourhood. But the sudden disappearance of this limestone, elsewhere continuous, and the prevalence of faults at no great distance, leave an impartial observer little doubt that one of the many dislocations of the country has here taken place, resulting perhaps from extreme tension or even traction of highly convoluted beds unable to yield further to a con-torting force that may have been accompanied by some amount of stretching effect.

The limestone re-appears about half a mile to the eastward at a little distance from a rectangular bend in the stream, thence forming the northern side of the ellipsoid. Here, again, the shelly band in No. 5 of the above section re-appears, the fossils, however, being too obscure to give much hope of their determination.

To the southward where the river leaves the gypsum and limestone by a rocky gorge near Bozhá Bándá the strata are also much disturbed; the southern rib of limestone, which half a mile to the west has a thickness of 50 or 60 feet, is here represented by only a few beds, and these on the left bank of the stream are inverted, inclined to the north and crushed over to the tertiary sandstone series, yet at a short distance may be traced higher up upon the hill overlooking the river on this side, recovering their position, and with the overlying sandstone beds assuming the southerly slope proper to that side of the anticlinal curve.

At this place, too, a mass of gypsum occurs in an unusual position within the lower nummulitic beds, and with much less regularity than is observable in the cases mentioned with regard to the intercalation of gypsum bands nearly in the same relative situation not far from where the meridian 71° crosses

the Manzullí and Bánda range (see page 110). Fig. 30 is a diagrammatic sketch of the structure seen on the left bank of the stream here.

13. Red clays and greenish-gray sandstones in thick alternate zones, more sandstone than clay.
12. Gray and purple sandstone and thin clay layers.
11. Red clay 15 feet in deep blackish purple thin sandstones.
10. Purple and gray sandstones and red clay.
9. Red clay much thicker in opposite bank of stream.

Crushed line of junction.

8. Hard dun *Alveolina* marble 6 to 20 feet.
7. Green clay.
6. Gray and white gypsum 15 to 20 feet.
5. Green clay, weathered olive.
4. Dark, cherty limestone with a flat-coiled shell like a *Planorbis solarium*, couple of feet.
3. Dark-olive shaly clay, in places blackish.
2. Dull-red clay passing towards (1) into a purple, earthy, coarse sandstone with ferruginous base 1 foot thick.
1. Red clay.

The junction of the red clay No. 1 with the gypsum of the interior is concealed, but at a little distance to the northward the latter is seen overlying black alum shales, with thin pieces of bituminous, hard, black, flaggy limestone scattered over their surface, apparently derived from the dark bituminous parts of the adjacent gypsum. The alum shales, from their decayed state, are evidently pyritous, and native sulphur in small quantities was observed in their planes of division.

To the eastward of this place the axis of the anticlinal seems to lie Eastern part of the very much towards the north side of the ellipsoid, ellipsoid. on the southern side of which a large mass of the tertiary sandstones has been apparently let in below the general surface of the nummulitic beds, and the contortions of the latter are seen to form strange elongated zigzags on the mountain side between the high tertiary ground and the eastern end of the hill.

Here the nummulitic limestone of both sides of these hills meets, forming a perfectly natural anticlinal U-shaped U-shaped Its eastern termina- tion. ending to the high ground from which the sandstones of the tertiary series slope into the neighbouring low ground.

The sketch (Fig. 31) is intended to represent the positions of the various rocks looking from where the Ismaíl Khél river traverses the gypseous series westward.

1. Place of rock-salt. 2. Gypseous series, gypsum, clay, and alum shale. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone series. F. Faults.

To the eastward of the Jatta ellipsoid an open plain sloping to the Teeree Towey (Tíri Taní) stretches out between this and the imperfect ellipsoid containing the quarries of Saya Malgheen (Séya Málgin), the distance between the two being about four and a half miles.

6.—*The imperfect ellipsoid of Saya (Séya) Malgheen (Málgin) (Salt quarries).*

The ellipsoid of Saya (Séya) is apparently formed on a continuation of the same anticlinal axis as that of Jatta, that is to say, they both occur in the same valley, and both lie between the same two longer ranges in such a manner as would suggest two upward undulations of one long anticlinal axis, there being no hills where the depression between would have carried the hard limestone rocks below the general level or incline forming locally the lowest limits of atmospheric denudation.

As usual in these features the ground is hilly, but little more than one ridge can be perceived, the southern side of the anticlinal imperfect. the anticlinal having for the most part apparently disappeared in a fault coinciding very closely with the adjacent part of the Teeree Towey (Tíri Taní) river bed, but where remnants are seen these are inverted.

This is not the only fault affecting the configuration and structure of the ground, the northern nummulitic limestone

Faults. rim being broken through in two conspicuous places as shown upon the map, besides adjacent smaller faults.

But the main features of the structure are beautifully preserved at

Anticlinal well seen at both ends of the ridge where the convex, smooth, ends of ellipsoid.

hog-backed surfaces of the nummulitic limestones like the ends of an inverted canoe of huge dimensions take the ground, and are successively covered one over another by sheets of tertiary sandstone having the same form and a common axis of curvature. This is most evident at the western extremity of the hill, the anticlinal being continued for a long way by the sandstone series between two synclinal troughs, in which the successive beds may be traced each within the hollow of another. Further east other contortions supervene, but towards the Indus the strata become more steady as the succession rises to the newer sub-divisions of the sandstone series.

The lower beds of the last named series rise high upon all sides of

Tertiary lower sand- the Saya hills, except that towards the Towey river, stones. where the slopes are of gypsum or gypseous débris overlying the salt. Between these two the nummulitic limestone forms all the higher crests and stronger features of the ground.

In the very lowest of the sandstone beds close to the nummulitic

Bone beds. limestones there are some highly fossiliferous layers full of bone fragments, such as ribs, terminations

of large bones, parts of skulls, and not unfrequently reptilian teeth. These beds are well seen on the pathway by which the salt is carried to the dépôt at Malgheen (Málgín). One slab close to the track contained, when the place was first visited, a large part of the rostrum and skull of a crocodile with several teeth (discovered by Dr. W. Waagen), but on a subsequent occasion this was searched for in vain, having probably been broken up in the interval, for many stones from these beds with the

appearance of having been freshly quarried were found collected near the spot as if with the intention of improving the road.

In the same layers with these bones, and having a somewhat wider vertical range than where previously observed, the same large thick-ribbed shell as was found near the Ismaïl Khél river again occurs, but in equally bad preservation.

Fossil exogenous (?) timber is also met with, sometimes in the lowest beds, sometimes higher up in the series, as in the valley between these Saya (Séya) hills and the ridge rising between them and Malgheen (Málgín).

In this and the neighbouring country, particularly to the north-east-ward and the north, perhaps because the exposures of the lower rocks of this series are more largely displayed on the flanks of most of the hills, the difference between them and the newer beds of the sandstone series becomes very marked, the deep purple colour of the strong sandstones and the brighter red of the clay zones being very conspicuous, while to make the contrast stronger, thick zones of very green glauconitic-looking sandstone frequently occur among these lower rocks.

The contact of these lower tertiary sandstones with the nummulitic limestone presents here no appearance of unconformity (any more than elsewhere), the very next bed to the limestone being highly calcareous, and containing numerous small nodules of brown hæmatite (as also observed beneath the limestone cap north of Kureerosum, (see page 94.)

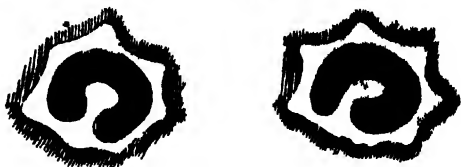
It had long been suspected from the many slight differences observed in the various junctions of these groups that the newer one certainly, and possibly the older one also, followed no rigid and unvarying succession in detail, but that more naturally they were subject to a certain amount of lateral change, not, however, sufficient to remove or conceal their distinctive general characters. An instance in point occurs here,

where there is a very peculiar layer made up of small slightly flattened calcareous concretions exactly like, if not exactly the same as, one very often to be observed close to or just above the limestone, but at this place separated from it by about 100 feet of the lower tertiary sandstones, the bone beds and the layer containing both bones and shells. Hence it may be assumed with an amount of accuracy depending on the identity of this peculiar layer that the basal beds of the sandstone series, though generally contemporaneous, cannot be asserted to be strictly so within narrower limits than the time necessary for the deposition of a hundred feet of rocks.

The red clay zone below the limestone is seen, but can hardly be said to show itself strongly, here, and the whole of the interior of the ellipsoid forming the southern side of the ridge is enormously covered with gypseous and reddish-earthly débris partly re-arranged naturally into a recent gypseous rock or tufa, and partly artificially arranged by the long continued operations of the quarrymen in extracting the underlying salt, (see appendix).

The gypsum presents the usual characters, being partially opaque and solid, white-gray or blotchy, and more frequently compact or granular than crystalline and translucent. The lower portion of it resting on the salt was found to be black and bituminous, and associated with some blackish clay like rotten alum shale, presenting carbonaceous, ferruginous, and gypseous appearances, and containing fragments of hard dark limestone derived from layers in the gypsum. Interstratified with dark coloured gypseous rock there was seen at one place a 2-foot layer of white salt, and in another as if lower than this, pale-gray, stony-looking gypsum, and a hard crystalline rock resembling a mixture of gypsum and limestone, in which were found some very small clear crystals of Anhydrite.

The stratification marked by these alternations was nearly horizontal, and being near the axis would coincide with the anticlinal



structure of the ground, as shown in the sections, Figs. 32, 33, and 34, of the Saya ellipsoid, (Malgín salt quarries) about one mile in extent, each.

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstones. F. Faults.

The salt of this locality will be found referred to in the appendix ;

it is of the usual dark gray colour, and like that of other eastern localities, the upper part is in places somewhat bituminous near where it is in contact with the overlying black bituminous gypseous rock ; from the situation of the quarries its thickness may be over 200 feet.

There is a rather large accumulation of boulders and débris along

Boulder accumulation. the foot of the hill west of Saya, now at a higher level than that at which the river runs, but which

may nevertheless have been brought together by the transporting agency of this Teeree Towey (Tíri Tauí) stream in former times. It appears to be quite local.

A little further down the stream is the village of Zertungí on its right bank, at which gold was said to be washed

Gold-washing. from the sand of the stream during the rains, the practice having given the name to the place (zer), meaning gold in Pushtú or the language of this country, and (tunga), a kuss, khud, or ravine.

The fault in the river here would seem to be considerable, and the

Fault in Teeree (Tíri) river. tertiary sandstones on its southern bank appear to form undulations in the bottom of what had once been a narrow synclinal trough.

The contorted state of the beds extends for miles down the course of

Contortions in its valley. the Towey (Tauí), but before this reaches the Indus, steady sections are seen on each side rising upwards in the newer rocks of the series.

7.—*The hilly ranges and their neighbourhood from Bahádur Khél and Soordag (Sárdag) country to Nundrukkt and Hokurmí mountains.*

Most of the hilly ground which has now to be noticed forms
 Form of ground. double or triple, often anticlinal, ridges sometimes
 with synclinal plateaux or other high ground, or
 deep valley, between the more elongated elevations. It first takes the
 character of a range towards the westward near Luttummer, where
 crossed by the Chungôsh river (called Chunghaze on the map), and here
 is formed of a central mass of tertiary sandstones and clays, rising to
 considerable heights, disposed in a wide synclinal curve or closely con-
 torted between two remnants of smaller anticlinal curvatures, respectively
 north and south of the former at the edges of the range.

The most northern of these anticlinals may be called the incomplete
 ellipsoid of Bahádur Khél, and the latter the still
 Ellipsoids. more imperfect one of Luttummer. Both occupy
 more or less, or coincide with, hilly ground trending in a direction ge-
 nerally-parallel with the range. From the summits of this high ground
 the whole range may be seen to expand into a mass of nearly horizon-
 tally-bedded sandstone hills in the country of the Wazeeris (Wazírís) to
 the westward, rising conspicuously above which
 Káffir Kôt. are the cliffs and pinnacles of an outlying patch
 of coarse conglomerates, known by the name of Káffir Kôt. (*)

The section would doubtless be interesting and instructive, ascend-
 ing through the whole series of the tertiary sandstones, but it is unfor-
 tunately, most of it, in forbidden ground. Directly south of Káffir Kôt
 almost every bed of the soft upper sandstones beneath that patch of

* Káffir Kôt is simply a mass of conglomerate washed into perpendicular tower-like shapes by rain. One of these towers was ascended with great difficulty and descended with greater, there being literally nothing to hold on by. The whole of the range from Káffir Kôt to the banks of the Koornu, some twenty-five miles to the west, is of the same formation. From information kindly supplied by Colonel H. C. Johnstone, Superintendent of the Punjab Frontier Survey, which quite corroborates the account given by the messengers sent the place (see pages 5 and 71).

conglomerate seemed to be visible in a southerly direction, with older beds coming out from beneath, as far as an anticlinal-looking limestone hill just beyond the meridian 70° 30' east longitude.

The lower part of this section comprising the usual gray and purplish beds of the basal part of the series overlies, curving and enfolding the western part of the Bahádur Khél anticlinal, where the nummulitic limestone may be seen conforming to the curves of the sandstones and followed within by the red clay zone intervening between the limestone and gypsum, the soft sandstone and shale or clay group with nummulites seen to the northward being absent here.

Starting from this place the limestone on both sides of the anticlinal as far as the Kurshrú Algad (stream) south of Bahádur Khél is either much disturbed or vertical or inverted as usual, appearing to *overlie* the sandstones, &c., *beneath* which it passes to the west. Towards its base it contains some marly light coloured bands full of fossils, large *Lucina* and such bivalves in numbers; also *cones* and some other *gastropoda*.

Fossils. In other layers it also contains the large thin *rotalina* so characteristic of the 'Subáthú' nummulitic bands in the Potwár; these, on the one hand, and the larger forms previously mentioned on the other, both combining to link together here and elsewhere

certain of the characteristics of the Salt Range and Subáthú characters. of the Subáthú nummulitic types in a way which may have some weight towards the identification of all three as belonging to the same 'Subáthú' nummulitic period rather than forming different eocene stages.

The red clays underlying the limestone display themselves most largely to the west where the axis of the anticlinal sinks, and the gypsum within occurs as a narrow zone, from the confused stratification of which little of the relations can be ascertained.

The inversion and crushing along the north side of the anticlinal Inversion and crush- would seem to have been accompanied by fracture ing. in some places, though probably of no great amount, for a highly coloured red band in the tertiary clay and sandstones occupies the flanks of the hills, outside of which comes a greenish and gray band, chiefly of sandstones, not unlike those of Dungôte on the Indus (eastward of Kálábágh), and these beds Greenish lower tertiary seem to be the same as those succeeding the lime- sandstones. stone where the positions are more natural. In one place at about 300 yards outwards from the limestone a thin band of conglomerate occurs in the green sandstone, containing both quartzite and tertiary sandstone pebbles, a local feature which has been previously noted in the lower beds of the series.

One of the salt localities of the district occurs in the gypseous Suppurri salt locality. series of these hills just on its north side, and on the watershed between the Chungôsh and Kurshrú streams. The exposure of salt, said to be small, lay concealed by fallen masses of the gypsum, but a strong white incrustation of the mineral was seen to mark the spot.

As the western termination of the ellipsoid containing the largest salt exposure in the whole district, a Section. cross section taken about two miles west of the Kurshrú gorge may be given to show the arrangement of the groups. Fig. 35 is a section across the hills, west-south-west of Bahádur Khél, about one mile in length.

1. Place of the salt a little to the west. 2. Gypsum. 3. Red clay zone with two sandstone layers at top. 4. Nummulitic limestone. 5. Tertiary sandstone series. F. Fault.

We come now to the salt field of Bahádur Khél containing its Bahádur Khél salt quarries, the latter forming a small feature of the locality. place, while the salt at once attracts attention, stretching for four miles up the valley of a small stream, which runs westward into the Kurshrú defile. For four miles further eastward the salt is less exposed, but the nature of the ground shows its presence

with an average width throughout, often approaching and sometimes exceeding a quarter of a mile. It is not only in the bottom of this little valley that the naked salt is seen, for it also forms much of the sides and rises with two conspicuous hills 200 feet in height in the middle of the glen. The whole of these hills are exposed rock, and the rock is salt, except a small capping of craggy gypsum on top, which looks in places somewhat disturbed and greatly weathered (see frontispiece).

The aspect of all this gray rock-salt is peculiar, often dull and icy, with irregular darker patches or blotches, giving Aspect of the salt. many of the beds a conglomeratic appearance, but which broken into are found to be perfectly clear and crystalline salt. In other places it has a blacker look, and thin muddy layers are not uncommon.

The stream in the valley is said to flow constantly and to be largely derived from springs; it is of course saturated brine running on a bed of but slightly concealed dark rock-salt strongly contrasting with the copious thick dendritic incrustation which almost entirely covers the stream, forming a surface of quite sufficient strength to support one's weight.

Notwithstanding that the exposure of the salt is so great, there are attendant circumstances giving a good deal Complexity. of complexity to the relations chiefly on the south side of the salt tract, but, fortunately, these are specially clearly seen just at the western extremity of the latter in the Kurshrú Algod gorge, where two streams meet south-west of Bahádur Khél. As the Kurshrú Algod sec- section exposed here is so highly instructive relation. tion. regarding the arrangement of the groups, and shows the proper place of the salt, it will be well to describe it briefly (Fig. 36) before considering that taken across the larger development of the salt near the quarries to the east.

1. Rock-salt. 2. Gypsaceous series. 3. Red clay zone. 4. Nummulitic limestone. 5 & 7. Tertiary sandstone.

Anticlinal.

NORTH SIDE.

SOUTH SIDE.

No. 7.	{ Red and gray beds sandstone and clay (crushed). }	Part. No. 7.	{ Red clay, sandy clay, and purplish-gray sandstone with two very red clayey zones, much crushed, 100 yards south of limestone. }	Part.	
No. 6.	{ Gray sandstone containing many lumps, blocks, pebbles, and irregular layers of dark-gray limestone. }	35' } 35' }	{ Coarse, gravelly, loose sandstone quite local, regularly overlying the limestone, contains nummulitic debris; dies out. }	5 to 7	
			{ Gray and variegated clay with large lumpy spongiform limestone nodules. }	4'	
No. 5.	{ Dark and pale-gray clay forming a thin layer overlying nearly white nummulitic limestone, fossiliferous ... }	55' }			
	{ Two bands of red and yellow clay near bottom of above, one 4 feet, the lower thicker ... }	67' }	No. 5.	{ Rugged, lumpy, nummulitic limestone, with a hard gray band in the lower 30 feet, fossiliferous ... }	70' }
	{ Gray clay or shale ... }	10' }		{ Alternating limestone and shale with four red and yellow clay bands ... }	4' }
	{ Thin band of hard nummulitic limestone ... }				
	{ Gray clay, 3-foot band ... }				
No. 3.	{ Purple and gray variegated clay 3' }	238' }	No. 3.	{ Purple and variegated slightly by green clay ... }	15' }
	{ Red, marly clay containing a 2-foot 6-inch band of sandstone (4) ... }			{ Red clay with sandy layers ... }	35' }
				{ Coarse, purplish sandstone (4) ... }	1' }
				{ Red clay ... }	6' }
				{ Coarse purplish sandstone (4) ... }	2' }
				{ Red clay with greenish layers below ... }	207' }
No. 2.	Compact white gypsum ...	32'	No. 2.	Compact whitish gypsum ...	40'

No. 1. Centre of anticlinal.—Gray and greenish clay with disturbed masses of gypsum and debris; also an exposure of rock-salt measuring 43 feet by 15 feet high; length between from gypsum to gypsum about 130 feet.

Descending this gorge from Bahádur Khél purplish-gray and red beds of the tertiary sandstone series are found at the northern side of the anticlinal dipping in inverted order southwards at 70°. They have a good deal of red clay intercalated as observed to the westward, and at their junction with the nummulitic limestone exhibit a broken, crushed, and disturbed appearance. The rock in contact with the latter is a gray sandstone with little trace of stratification, and containing both lumps and irregular layers of dark gray, compact limestone with few traces of fossils, and more rarely small white *alveolina* limestone pebbles, containing these forms. It contains also plant impressions, thin coaly strings, small bone fragments, and pyritous nodules.

The junction line is here, both as regards this sandstone and the nummulitic limestone, very irregular; at one place purple clay touching

the limestone, at another this sandstone with a thin dark-gray clay layer between. The surface of the uneven limestone does not look like one of erosion, and the appearance seems due to the effect of pressure upon rocks of unequal hardness.

The adjacent nummulitic limestone is of very light colour and contains numerous fossils. Interstratified with it are two red and yellowish clay bands (Fig. 37); the upper, 4 feet thick, and the lower, thicker like it, but containing lumpy calcareous nodules. Next to the strong band of limestone is a 3-foot layer of gray shale passing into the top of the red clay zone which is here marked by another 3-foot band of gray and purple variegated clay. For a great thickness below, this smooth, bright red

a. Nummulitic limestone. b. Gray sandstone. c. Red and gray sandstones and clays.

clay occurs, with few traces of stratification nearly vertical and inclined somewhat to the south if anything. It is here and there covered with a white efflorescence, and not far from the top contains a well marked band, 2 feet 6 inches thick, of purple sandstone, in parts conglomeratic, from small quartzite pebbles.

Below the red clay, in the middle of the section, are apparently two bands of nearly vertical gypsum enclosing between them a confused mass of greenish-gray clay or '*Shcenkoura*' with great detached blocks or masses of gypsum (one of which measured 30 feet across). Within this clay there is also exposed some of the rock-salt, its relations being very obscure, having little connexion with the arrangement of the clay and being partly concealed by débris. These two gypsum bands have quite the same character and nearly the same thickness, and, moreover, as the whole section is repeated on the south, it becomes evident that they once formed the sides of an anticlinal curve.

The red clay zone is some 40 or 50 feet thicker on the southern side of the axis than on the north, and the purple sandstone band is here represented by two similar

South side of section.

layers. The uppermost portion of the zone, a band of pale purple clay, is also here proportionately thicker, and contains lumpy calcareous layers and nodules which increase upwards in quantity till they form the first bed of the nummulitic limestone.

Fossils are not seen in the lowest 4 feet of this limestone, where shales alternate with it, there being four red and yellow earthy beds among these, the lowest of which is the thinnest. A hard gray limestone band like that on the other side of the axis here occurs higher up in the group, and the upper portion of the latter is rugged and very lumpy nummulitic limestone with several of the usual fossils.

The junction beds of the tertiary sandstone here are somewhat unusual, the corrugated surface of the limestone being covered by 4 feet of gray and variegated clay, with large irregularly rounded limestone concretions or nodules. This is succeeded by a coarse, gravelly, loose sandstone, largely composed of nummulitic limestone debris, 5 to 7 feet thick, and following the clay and limestone stratification quite regularly. It is, however, quite local, and does not appear on the opposite bank of the stream. Over this come the red clays, sandy clays, and purplish or gray sandstones as usual. At the lower positions in this tertiary series the whole section is one of considerable interest, showing, as it does, the true structural relations of so many of the groups in a country where most of the appearances are apt to mislead.

With regard to the relations of the salt and clays and gypsum, which are so obscure in the centre of the section, much of the obscurity disappears on ascending from this gorge the little stream of the salt quarries valley, which unites with the Kurshru Algod by a rocky fall in the tertiary sandstones at the southern side of the above sketch. Having reached the axial region, the salt, of which from 10 to 15 feet in height is exposed, is found horizontally arranged below gypsum, also horizontal, and some 15 feet of greenish clay intervening between the two.



Fig 35 Section W-W of Bahadurkhal



Fig 36 Section on left Bank of Kurshru alga



Fig 37 Junction of Nummulitic limestone and Tertiary Sandstone N end of Kurshru section



Fig 39

Fig 38 Section through Bahadurkhal Salt locality. Eastern Salt hill 100 feet above top of Peak



Fig 38 Section through Bahadurkhal Salt locality

A little further on the salt clay and gypsum with the same arrangement takes even more the appearance of an open curve, but complications soon set in, the stratification of the salt becomes vertical or curved, so as to correspond with the northern side of the anticlinal into which the stream seems to have worked its way.

From this place to where the road to Bánnú crosses the salt, some
 Faulted southern gypsum and less of the nummulitic limestone is
 boundary of salt. seen edging the salt, but close to the road the
 latter disappears entirely, and soft red clays and tertiary sandstones
 coming into junction with the salt, the crushing and confusion displayed at the faulted contact is extreme. In the line of the fault small and apparently displaced representatives of the gypsum, the red clay zone with purple sandstones in its upper part, and a little of the nummulitic limestone growing thinner downwards, are inverted, dipping at high angles in a northerly direction.

Not far from the road and south from the furthest eastward of
 Gypsum capping tertiary sandstone. the two hills (one of which is seen in the frontispiece) there are some horizontal patches of the gypsum forming caps upon hillocks of red clay and tertiary sandstone, while in the same neighbourhood more of this gypsum rests partly on the same sandstone series and partly on the salt, see Fig 38, which shews the section through the Bahádur Khél salt, east of the quarries. Bearing in mind the Kurshrú Algud section and its arrangement, it is difficult to account for such appearances as these except under the supposition that before the ground assumed its present denuded form, the solution and removal of salt beneath allowed portions of the gypsum to slide bodily from their places to lower positions.

1. Rock-salt, 1,500 feet exposure. 2. Gypseous series. 3. Red clay zone. (4. Sandstone in 3.) 5. Nummulitic limestone. 6. Tertiary sandstone series. F. Faults.

The salt of this exposure and method of working it will be found fully described in the appendix, so that it will be sufficient to mention its relations here as one of the rocks of the country only.

Fig. 39 is a reduced sketch of a rough survey from one side of the

Thickness of salt.

salt exposure to the other with the dips marked, from which it has been calculated that

the thickness of the salt at this place is from 1,000 to 1,230 feet, or even more. Its stratification is almost everywhere distinct, and rendered more evident by thin earthy layers alternating with the beds. Here the dip is everywhere northerly—in the lower beds from vertical to 70° declining to 50° or 55° , forming a bold half arch in the central hills, again high after passing these, but gradually becoming lower to 30° , where the last of the salt is seen. There are only two points, marked *a* and *b* on the plan, where some curvature of the beds or disturbance of the steady high dips occurs, likely to reduce the total thickness of the section, and these curvatures appeared to be quite local, not being traceable for any distance, but though the consecutive high dips follow from bed to bed, the strike is not parallel throughout, a result which may be due to pressure or even to concealed fractures or faults, though no such features could be observed in this section, the only marked divisional planes indeed, besides those of bedding, being some strong nearly horizontal joints.

The gypsum capping the central hills presents more difficulty with

Gypsum capping central hills, and their relations to the rest of the section.

regard to accepting the measured thickness of the salt as true. That to the north succeeds the salt as elsewhere with apparently perfect conformity.

The capping on the hills has the same arrangement as already noticed to the west in the interposition of a greenish-gray clay band between it and the salt, and there is, at all events, a certain amount of parallelism among these beds. Still it is clear that if the salt beds to the north of the hill were produced upwards, they would pass, even at a much lower slope, far above the outlying patches; hence, if the latter are conformable and in their original place, they must either have been embedded in the great salt deposit, or else, being really the lower part of the succeeding zone, the enormous thickness which the salt exhibits must be

a false appearance due to concealed faults or to curves the connexion of which is no longer visible.

But these cappings of gypsum need not necessarily be now in their original places, we have the same rock to the south in utterly abnormal positions, and there is no good reason why these two patches should not also have transgressively subsided from higher levels owing to dissolving of under-lying salt; the situations in which they rested having decided the formation of the hills, to the soluble strata of which they formed a protection against the atmospheric erosion.

One of the hills considered by itself presents much the appearance of half of an anticlinal curve, and where inversion of salt. is so common (the rule rather than the exception) there would be little difficulty in supposing the salt beds to the southward all inverted, if any clue could be found to the fact beyond the reversed dips of some portions of the series just at the line of fault (already mentioned) where local complication lessens their value.

By introducing faulting to the north of the hills, the appearances might also be explained with great probability, but of this no evidence has been detected.

The similarity of the salt-rock throughout gives it as a mass a unity of character, rendering contortion repeating the same beds more probable than dislocation; a similarity of salt-rock throughout against faulting. sameness of aspect, too, all but fatal to the hope of discovering repetitions among the layers; more particularly as these are in places strongly obliquely laminated (or false bedded) inducing distrust of discordant appearances.

However the case may be, the fact remains that a cutting 1,500 feet in length could be made as the shortest straight line from side to side through highly inclined rock-salt and nothing else, except the small quantity

Possible reduction of thickness incapable of proof.

of clay associated with it, yet it does seem strange, that while the anticlinal structure pointed out to the west recurs even more strongly about a mile and a half to the east, its disappearance should be accompanied at this the widest exposure of the salt, by an apparently enormous thickness of the deposit, and at the same time the clearest evidence of disturbance at the place, instead of explaining this appearance, should be limited to a large downthrow fault at the outer limit of the salt to the south, which it is not easy to connect in any way with the usual thickness of the salt itself, a thickness which, even if capable of reduction from the above considerations, would still remain large, probably from 350 to 700 feet.

The gypsum succeeding the salt takes its usual place near Surreenda

Gypsum. on the south of the exposure, and thence eastward

is often seen the red clay also overlying it, but the nummulitic limestone is much thinner than usual. Northwards of the last named village, and on the opposite side of the salt valley, the gypsum spreads out over bench-like hills lower than the nummulitic limestone escarpment cresting the village and regularly succeeds the salt.

Red clay zone. Above it the red clay zone comes in its proper place, occupying depression at the foot of the

limestone outcrop, having near the base of the latter a well marked band of strong purple calcareous sandstones weathering of a very dark color. These are about 10 or 15 feet thick, (to judge from their broken outcrop); they contain black, flinty pebbles, and on looking over their weathered surfaces some small fragments of bones were found embedded and one small portion of an apparently reptilian tooth. The band is evidently a larger development of that found on

Fossils.

the same horizon in the Kurshrí section and to the west, while the fossils mentioned and the nummulitic layers observed south of Teeree are the only kind of organic remains met with in the whole of the red clay group.

In the nummulitic limestone above are some layers largely formed of shell fragments, apparently the remains of oysters,* and higher up numbers of the ordinary nummulitic fossils, generally in an imperfect state of preservation. The limestone has much the same thickness as at the Kurshúr Álgud; it curves with an increasing dip to the northwards, and occupies most of the tunnel, by which the road issues from the salt valley into that of Bahádur Khél, near which excavation it becomes nearly vertical.

The usual lower beds of the tertiary sandstone series succeed, dipping off the hill, but becoming rapidly perpendicular along the southern side of the Bahádur Khél valley and in the large nullah running along the foot of the salt-quarry hills westward. Very brightly colored red clay and gray sandstones alternate; they are either vertical or dip to the southward as a rule, but half-way between Roghá (Rághú) and Bahádur Khél are closely contorted.

Towards the middle of the Bahádur Khél valley are soft gray sandstones and red clays, with pebbly bands and occasional greenish-gray shaly clays more or less covered by detrital accumulations. The dips are generally high, and also to the south more frequently than in other directions, the beds being probably a good deal folded here and there. The character of the rock indicates a middle or even somewhat higher place in the series.

In the eastern portion of the Bahádur Khél salt exposure, the salt is seen to form an anticlinal arch with a dip of 50° to the south and 60° to the north, near the Kundo Tapu or boorj. From this towards Rágho it is more concealed by gypsum with black shaly layers and by débris. Its stratification seems to undulate, one dip to the westward having been observed, but to the south

* It was presumably some such beds as these which Dr. Verchere observed, drawing the inference that they were jurassic from their resemblance to other shelly limestones near Kalabagh.

of its area it conforms to the southern side of the anticlinal curve, there strongly indicated by the overlying strata. But on the northern side of this curve, nearly midway between Rágho and Bahádur Khél, the different groups are much disturbed where two small and rather isolated hills stand out from the adjacent ridge.

The most easterly of these shows several slips, repeating the out-cropping beds of the red clay and nummulitic limestone groups, and these are faulted against the adjoining tertiary sandstones, a few beds of which occupy a small contorted trough towards the western hill.

The limestone here apparently retains its thickness of 50 or 60 feet, but the hard upper *alveolina* beds were not observed, those forming the local upper part of the group alternating with shaly bands and being highly fossiliferous. At the base of the limestones here are some thin, white, chalk-like layers, one of which is very conspicuous. These white, marly, chalky-bands continue

downwards into the variegated clay below, in which three or four of them occur; this clay has the same pale purple tint as in the Kurshrá section, but here it contains many small nodules of brown hæmatite and little concretions stained of a brilliant greenish-blue as if by copper. Below this clay the coarse liver-coloured sandstones of the red clay zone are much exposed, alternating with red clay layers and forming a band of 20 or 30 feet in thickness. They are here conglomeratic, and again were found to contain bone fragments. The rest of the red clay group below is much overrun by débris, but seems as thick as usual.

To the eastward of these hills the axis of the Bahádur Khél anticlinal comes out obliquely on the plain or valley to the north, and is cut off by the continuation of the fault at their northern side. Gypsum and gypseous débris with occasional salt exposures and many crater-like hollows indicating its existence

below occupy the whole of the interior of the curve, and bend round the northern slopes of the hills to adjoin the Nurree (Nurri) outcrop beyond

Southern side of anticlinal. Rágho. The remains of the southern side of the anticlinal rise boldly, forming a fine portion of the

arch from Chárpurrá to Shoh (Shágh) and on eastwards to Nurree. In the gypseous series below Shoh one mass of gypsum rested at an angle of 30° unconformably upon reddish gypseous clay rendered flaggy by gypsum layers, showing its stratification inclined at 60° in the same direction as the overlying patch. This is supposed to be another instance

Gypsum series. of subsidence, *en masse*, of portion of the gypsum owing to removal of its support. In the same

vicinity the series seems to have a larger thickness than usual, for regular interstratifications of gypsum and greenish clay in 10 to 50 feet bands undulate to the southward at 45° with a thickness of nearly 300 feet above the salt.

The 'red zone' follows in its place, showing a transition from the gypsum by alternating ripple-marked layers of the latter with red clay, but the nummulitic limestone has greatly thinned away, there being in

Transition by ripple-marked gypsum layers into red zone.

some places but 15 or 20 feet of yellowish, calcareous, marly beds to represent it. A few feet above these, there is a peculiar band among

Concretionary bed above limestone. the tertiary sandstones, almost entirely made up of balls of limestone enclosing sometimes black

chert nodules. This band makes itself very evident from the way in which its concretions strew the ground, and may be looked upon as, perhaps, the last trace of the calcareous rock producing conditions of the group preceding. Concomitant with thinning out

Thinning out of limestone.

of the limestone, there are near the highest point of the ridge evidences of unequal accumulation of the materials forming the succeeding group; a thick layer of purple clay which rests on the limestone being seen to thin out to nothing, so that an overlying band of sandstone takes its place. Twenty feet above there is a band of

conglomerate in these sandstone beds, containing numerous pebbles of limestone with *alveolina* and *nummulites* enclosed, both in the pebbles and in the base. Flinty, cherty, and sandstone pebbles of the same kind as the beds above and below this conglomerate also occur with the limestone ones, so that this may be one of the shore deposits of the early part of the tertiary sandstone series, the derived contents of which certainly afford no more evidence of unconformity between the limestones and sandstones than of unconformity within the latter group itself, but may rather indicate formation in shallow water, within reach of wave action, or of distribution of materials by along-shore currents.

The same general succession and southerly inclination of the series of groups extends from hence towards Chárpurrá, North of Chárpurra. north of which place a section of the ground would show again the anticlinal position of the rocks with the salt in the centre conforming to the curve, and the overlying groups dipping north and south at angles up to 50° and 60°.

The great central synclinal of the lower tertiary sandstone series between the Bahádur Khél and the southern ridges of the range, where it is broadest, forms wide open curves with steeply sloping margins, the convergent inclinations becoming less towards the centre of the trough, in which situations the beds are nearly horizontal, the latter position having evidently added to their power of resistance to atmospheric erosion; thus the high plateau of Esár, almost surrounded by precipices, has remained, and the higher mountain to the westward reaching an altitude of 2,838 (+70=2,908) feet. Where the synclinal becomes constricted to the eastward, the beds are longitudinally faulted, and where the sides approach to the westward, compressed and complicated folding of the rocks takes place. (See section Fig. 41).

Faults.

The rocks which form the synclinal curve are well seen along the Bannú road from Bahádur Khél. Purple and red beds with much red clays are found 100 yards south of where the road leaves the salt at the salt quarries, and the usual gray and purple alternations are crossed to where the road descends an incline beneath the fine cliff called 'Yágoashú cumber' west-by-south from Esár. This is formed of thick gray sandstone with a few dark-gray shale bands below, overlying 150 feet of red clays, the contrast between the textures of these two thick groups having doubtless favoured the formation of the cliff. Among the sandstones at the lower part of the section here some conglomerate layers as before noticed were again observed. From beneath this cliff the road again ascends to the pass of Soordag (Súrdág) through a narrow strike valley where bright red clays predominating among the sandstones give the name to the locality.

The lower beds of the latter are seen sloping steeply downwards from the limestone surface which sheets the upper part of the Rindghur mountain south of the road and leaving one or two thick projecting patches on its side.

Towards the southern entrance of the pass where the road turns sharply in that direction to leave it, this Rindghur mountain sinks abruptly, while a lofty wall of the tertiary sandstone and clay series, chiefly gray sandstones above and red clay below, rises for many hundred feet immediately to the north of the road, strange to say, capped at its summit by a small patch of the nummulitic limestone. This place is evidently a focus of complicated crushing and faulting, in the midst of which, close to the base of the northern cliff, and, as it were, passing partly beneath it, is a narrow band of the rock-salt which was traced in a westerly direction for 600 yards, with small masses of gypsum and a portion of the red clay zone along its southern side.

The whole series of the Rindghur mountain is here, as it were, cut out, and directly in its strike are low hills
 Newer tertiary beds. formed of reddish drab clay with pale whitish-green sandy layers, and broken bands of very soft coarse sandstone, in which may be recognised a portion of some of the highest beds of the tertiary sandstone series. So that here, whatever may be the united thickness of the whole five groups of the country, we have a fault bringing some uncertain portion of the highest against the very lowest rocks of the whole succession.

Among these low hills, resting upon the soft upper rocks in some spots, or confusedly occurring among them, are
 Section. very considerable fragmentary patches of the lower shaly portion of the nummulitic limestone. Fig. 40, shews the section at entrance to Soordag pass (Súrdág pass) (about one mile)—

1. Rock-salt. 2. Gypsum. 3. Red clay zone. 4. Nummulitic limestone. 5. Lower tertiary sandstone. 6. Upper ditto. 7. Detrital accumulation. F. Faults.

The salt here is of the same character as that at Bahádur Khél, and shows itself in exposures of from 5 to 30 feet
 Details: the salt. high, rising over small spurs which separate the local drainage and holding its way in a tolerably straight line for the interior of the Luttummer anticlinal. The salt is not everywhere visible, being covered by a coating of gray saline clay, on digging into which it may be exposed; this clay seems to have resulted from the decomposition of the salt itself, and is only found along the narrow line which it occupies. The width of the salt varies from a few feet to two or three yards; in some places it appears nearly horizontally stratified, in others to dip northwards at high angles. Towards the west it is covered with disconnected patches of gypsum, having a like high dip to the north.

Some remains of the red clay zone are associated with it, and in these layers of the purple sandstone peculiar to that group also appear.
 Red zone.

Gypsum occurs in two bands, one close to the salt, the other parallel to, but separated from, the former, by the red clay band just mentioned.

In the face of the cliff above, two portions of curves in the strata appeared to be marked by the alternations of color of the gray sandstones and red clays as shown in the section. The lower red portion seemed to repeat much of the appearance of the band at the 'Yagoshu cumber', but it would be impossible to say that some of the clays of the red clay zone were not also present.

On reaching the small cap of limestone at the upper edge of the cliff it was found to be composed of a few beds of *alveolina* limestone, weathered and shaken, and having no relation to the sandstones on which it rests, the limestone being nearly horizontally disposed, but the sandstones beneath dipping northwards at a considerable angle; the remains of a similar patch were seen at a little distance to the east 25° north. Here also, as if passing below the *alveolina* beds, were a few layers of nearly horizontal, dark, earthy limestone containing rolled *nummulites* and lumps of *alveolina* limestone such as might have formed the uppermost part of the limestone series.

Almost from the same spot the northern side of the Lutttummer Luttummer anticlinal nummulitic anticlinal commences, inclined at a high angle to the north, so that it would appear as if this small outlier had once formed a vertical continuation of that limestone band, and when deprived of support had fallen over to the north. Either this or some complicated combination of slipping and faulting must be supposed to account for such an extraordinary occurrence.

The Lutttummer anticlinal is a feature of exactly the same type at that of Suppurri to the north (already described as the commencement of this division), but is completely overthrown, both sides of the compressed curve dipping to the

northward at high angles, the apex sinking westward as in the former case, and the southern side apparently sharply reflected upon itself, so as to bring the red-clays of the red-zone into view beneath the limestone both within and outside its southern limb. The gypsum band in the centre is very narrow, the red clays more largely exposed, the nummulitic limestone thinner than usual, containing the usual fossils, and the tertiary sandstone series with a conspicuous red clay band below sweeps round from the northern side, over-rolling and continuing the expression of the anticlinal in finely marked curves to the westward.

The ground immediately south of this anticlinal between it and the

The southern flanks of the hill inexplicably confused.

Bánnú road baffles all effort to realise its complicated structure. Large, continuous, contorted, or undulating masses of yellow, shaly, or marly nummulitic limestone containing thick *nummulites* and other fossils project, or overlie apparently the newer sandy clay series. This limestone may have a thickness of over 100 feet, and is succeeded apparently by some of the lower tertiary purple and greenish sandstones and red clays, near which another crag of limestone without any visible relation appears. In another place the newer tertiary soft beds seem to form a dome-shaped mass surrounded by an imperfect ring of the shaly nummulitic limestone, the débris of which dresses all the hills in the neighbourhood, giving the ground a dirty orange colour and smooth barren look.

The soft, coarse, gray sandstones and brown clays of the upper tertiary series are much disturbed, very fragile, and

Upper tertiary.

sometimes contain thin veins of heavy spar and occasionally also conglomeratic layers, the pebbles in which are formed of granitoid or other crystalline rocks, with an odd one here and there of *alveolina* limestone, showing that the strange conditions which enabled these latter to be transferred from the place of their formation without any appearance of unconformity between the two groups extended throughout nearly the whole of the newer series. Fig. 41 is a

diagrammatic sectional view of the arrangement of the groups from side to side of the range crossing both the anti-clinal and synclinal curves near the ends of the former.—

Section.
•

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone 6. Upper beds of same. 7. Detrital accumulations. F. Faults.

Along the southern base of the hills here from about Lutttummer Stony belt at foot of by Soordag and on beyond Goorooza there is a hills. stony belt little inferior in its barrenness to that which is so marked at the foot of the salt range. Its pebbles are formed of the local rocks, and the material, when sections can be seen, is well stratified sandy and stony clay inclined to the southward at angles under 30°. Beyond this zone to the southward all the country is a sandy flat traversed by the broad and shallow beds of dry nullahs, sometimes over a mile in width.

The southern side of the Rindghur mountain overlooking this low South side of Rind- ground eastward from Soordag (Súrdág) also repeats ghur mountain. in a great measure the features of the southern escarpment of the salt range; its crest is formed of the hard nummulitic limestone, beneath which some gray clays and the red zone are partially seen, the latter still containing its dark purple sandstone band at top. This soft zone occurring along the outcrop (as in the salt range) has favoured the slipping downwards of great masses of the limestone and other beds below it; false outcrops of these Salt range character. rocks being found on the flanks of the hill resting upon the same drab and reddish clays and coarse sandstones of the upper tertiary bed as occur to the north of Soordag. Except where these subsided masses project there is little to be seen on account of the thick coating of débris with which the slopes are dressed. To the eastward (over a place where a village or hamlet called Sumkilla seems to have once existed) the gypsum appears from beneath the red zone with a thickness of 50 to 80 feet, much entangled with gray and reddish

clay, the underlying salt being seen in the beds of small nullahs which cut through thick displaced masses of the gypseous series. The latter

Gypsum: passage into was here again observed to pass by numerous red clay.

platy alternations into the purplish red clay above, these harder bands being ripple-marked, and at the place of transition partaking of the color of the upper rock. Some green clays (*Sheen-*

Green clays. *koura*) are seen below masses of the gypsum, and

the whole hill side presents such a confused and disordered appearance, that there is little certainty about the relations of anything below the beds forming the scarp and crest of the hill.

In the continuation of the Kurshrú stream at the east end of this

Rindghur mountain (here called the *Záwá Álgud*),
Goorooza section.

a more satisfactory section of the rocks is exposed, from the rock-salt upwards, the latter occupying a width of 200 yards, or 560 paces, measured in the bed of the stream (see Fig. 42).

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone.

6. Upper ditto. 7. Valley beds; detrital, hard, sandy, and conglomeratic. F. Fault.

Dip north, under 45°.

6.—Salt, gray sandstone, and reddish clays.—Upper tertiary sandstones faulted.

5.—{Tertiary sandstones, gray sandstones, with a strong band of purple} Several hundred feet.
clay; below lowest bed a layer of purple clay

{Solid nummulitic limestone—*Alveolina* horizon. 96 "

4.—{Nummulitic limestone alternating with shales, most shaly below 90 to 100 "

{Black shales, with a thin irregular layer of whitish, waxy, soapy clay near top 6 "

{Thin, lumpy, calcareous layers 3 "

3.—{Violet variegated clay, hard, light coloured and soft red and gray ... 10 "

{Red clay, sandy at top, with two sandstone bands, lowest 4 feet, upper 9 feet ... 400 "

2.—{Gypsum, compact, whitish, and gray 30 "

{Green clay 150 "

1.—Rock-salt measured horizontally, bedding not clear, exposed for ... 1,400 "

This large exposure of salt is almost due south of the quarries at

Rock-salt. Bahádur Khél, where the horizontal width was

little larger; here the bedding lines could not be distinguished with the same facility as there, probably by reason of the lower situation having favoured the accumulation of débris and increased the effect of meteoric water passing over the surfaces. If a general dip of even 35° be allowed for the salt here, however, which would seem lower

than the average angle, it would give a thickness of 700 feet for the deposit.

In the gypsum series the gray clays again appear in the same place as at Bahádur Khél, but the overlying gypsum itself seems unusually thin.

The red clay zone, on the other hand, is very thick. Narrow veins of gypsum traverse the clay, and some of the joint surfaces have a dark shining filmy coating as though of iron or manganese. There are some greenish bands in it towards the base, and its stratification is shown by slight differences of colour or texture. The sandstone bands near the top are also again present. This clay is, as usual, closely united with the pale purple or violet band at top, which appears to form the base of the nummulitic zone almost as much as the uppermost member of this.

The dark gray clay or shale succeeding the first few beds of the limestone has a general blackish look, its position reminding one of the nummulitic alum shales of Chichálí pass to the south, or the dark, pyritous and coaly layers in the Búkkh ravine (near Namal) in the western Salt range. The *alveolina* layers do not begin to appear in this section till half-way up in the nummulitic group, the *nummulites* are most developed also about the middle; and the lowest fossils are small *turritella*-like gastropods and fragmentary oyster shells.

The lowest bed of the succeeding tertiary sandstone series is a purple clay band: some sandstone beds of purplish and gray color succeed, then the thick red clay zone seen beneath the 'Yágoeshú cliff,' capped by the strongly bedded soft gray sandstones of Esaár, but these could only be seen, not reached, from the gorge, the way being, as usual, barred by a cliff with a deep waterpool at its foot where the limestone crosses.

The whole of this Goorooza (Gúrúza) and Soordag (Súrdág) country suffers much from want of water, that of the Bahádur Khél and Kurruck streams being salt, while the inhabitants prefer carrying it from near Luttummer upon donkeys, to constructing tanks or repairing these when broken.

The only spring that was heard of in the whole country was a very small escape of by no means good water at the limestone outcrop high above the right bank of the Záwá Álgud.

Just at the southern limits of the salt there was observed a small exposure of the upper tertiary soft gray sandstones and clays faulted against the former, and soon covered over by thick, well stratified, hard, sandy, conglomeratic and earthy beds of the detrital accumulation flanking the hills, and having a very decided dip to the south with a predominant reddish color.

At Goorooza (Gúrúza) near the chowki or boorj, a small weathered patch of the limestone rests upon these beds at a considerable distance from the hills, in the same way as some of the craggy patches from this to Luttummer, and although more than half a mile from any projecting exposure of the same rock, this has to be supposed to have reached its present position by means of former landslips when the configuration of the ground may have been very different.

Close by Goorooza (Gúrúza) to the eastward, the soft gray sandstone orsands, and pale red clays with coarse, rusty, loose, gravelly bands of the upper tertiary are again seen dipping northwards close to the salt, and there are sections showing apparently broken and fragmentary bands of marly nummulitic limestone wedged and crushed among the sandstones, fragments perhaps of the corresponding side of an antilinal curve which once continued in an arch from beneath the central synclinal over the gypsum of the adjacent

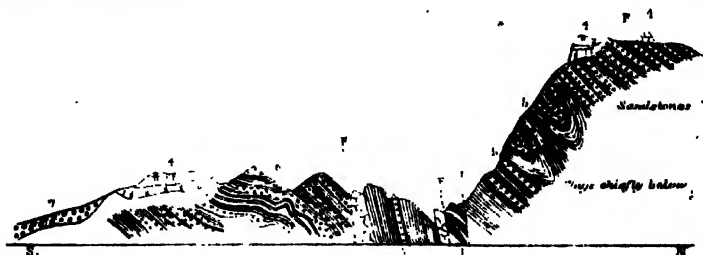


Fig. 40 Section of country to Gooling Pass, about a mile

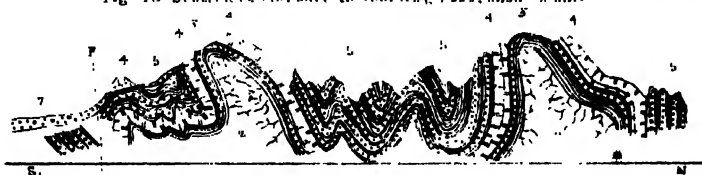


Fig. 41 Section between Bahadurpur & Lathumner



Fig. 42 Section near Gooling Pass



Fig. 43 Section of Nummulitic land E of Gooling Pass

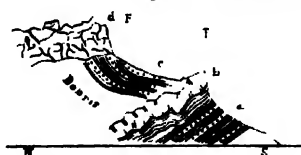


Fig. 44 Western aspect

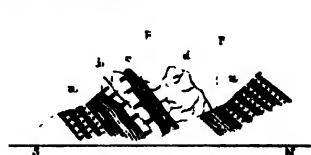


Fig. 45 Eastern aspect

Nummulitic bands E of Gooling Pass

Kurrak Salt Quarries

Konghu

Raghu R



Fig. 46 Section from near Kurrak to near Raghu R

outcrop. One little section of a few yards showed the succession as given in Fig. 43.

a. Gray and red soft sandstone and clays, upper tertiary ? b. Purple sandy clay. c. Gray sandstone. d. Marly nummulitic limestone. e. Purplish gray clay. f. Red and gray tertiary sandstones, not so like the upper beds as those seen to the west. g. Debris.

At another place close by a band of the limestone seemed to have been pushed horizontally over the soft sandstones which dip to the north at low angles, and in several places a mass of these tertiary sandstones was seen in close contact with the outcrop of the gypsum and salt, but capped by small patches of either limestone, gypsum, or the greenish gypseous clays.

From these facts and the general appearance of the junction elsewhere; reason has been found to conclude that the whole of the Bahádur Khél and Húkaní range from Luttummer to the Shukkurdurra (Shakkardarrá) country is bordered by a continuous line of fault along the southern side of the hills, the down throw of which to the south differs in different places, but the general effect to the westward has been to place very high beds of the tertiary sandstones in junction with the salt and gypsum. This great dislocation extends for over forty miles, and in a district where so many disturbances of the kind exist, it has for sake of distinction been called the 'Báruk fault.'

Two narrow nullahs from the eastward unite at Goorooza (Gúrdza) between which a rounded, elongated hill with a thick covering of gypsum over gray clays rises high enough to be visible from long distances, coming out from beneath this gypsum at its faulted outcrop along the right bank of the southern nullah; the rock-salt also crops with an apparently varying thickness of 15 to 20, and sometimes even much more than 50 feet; where not visible, its white 'shor' offlorescence is frequently seen, enabling it to be traced for more than half the length of the little valley, obscurely associated with the fallen masses of gray 'Sheenkoura' which intervene

between it and the gypsum. The opposite side of the glen exposes red and gray disturbed tertiary sandstone and clay beds, or the unconformable surface deposits sloping to the south.

Among these tertiary sandstones, &c., are beds having much more the aspect of the lower than the upper part of the series seen to the west. They are all disturbed, dipping northwards at 40° , 15° and 20° , and sometimes show synclinal curvature pushed over to the south. Intercalated in a purple portion of these beds, shaly below and with sandstones above it, is a thin, yellow, marly nummulitic layer, the association of the rocks much resembling the thin limestone bands of the Subathu rocks along the northern side of the Potwár country. At another spot a little to the eastward similar thin bands of limestone were again noticed in these purple and red tertiary rocks. One side of an exposure near a saline spring showing an appearance so different from the same viewed a few paces to the eastward looking back towards

the first that these (Fig. 44. and Fig. 45) may be worth representing to show the complicated structure of the ground along the line of fault. Fig. 44 shews the western, and Fig. 45 the eastern appearance—

a. Purple and red tertiary sandstones, &c. b. Nummulitic limestone with *Alveolina* and *Nummulites*.
c. Tertiary sandstone, &c., again. d. Gypsum, fault between b and d., and slips also probably adjacent.

The limestone in both cases *appeared* to be truly intercalated in the purple and red tertiary sandstones, but it could not be ascertained whether both were parts of the same band slightly displaced by slippage, or whether the eastern, which lies a little to the northward of the other, was a different and somewhat thicker layer. Neither exceeds 2 or 3 feet.

It is difficult to say what combinations of slipping and faulting may have occurred here, but further east towards the head of the nullah, where the tertiary sandstones are much contorted, the anticlinal axes sloping to the eastward, displaced patches of the red clay zone occur, and in one bank, lumpy, marly limestone such as that abovementioned, was seen in an inverted

section overlying purple clay and sandstone, and succeeded by some of the deep red clays of this older zone, showing that inversion, as so frequently the case, has added to the local complexities, and very probably aided the disturbed and broken rocks in settling into anomalous positions.

Although the junction beds have here no longer the upper character previously described, that these upper beds occur-
Upper tertiary beds disappear. ed at no great distance may be inferred from the large proportion of crystalline and granitoid pebbles occurring among those of the local rocks in the bed of the Álgud.

The northern nullah traverses the thick red clay zone beneath the
The northern nullah outcrop of the nummulitic limestone (here rapidly
east of Goorooza. ly growing thin) and that of the overlying lower sandstones, these forming the openly undulating south side of the great central synclinal trough. The diminished thickness of the limestone here may be noticed in connexion with the small show it makes among the complicated exposures just now mentioned.

The summit of the gypsum ridge forms a commanding point of
Summit of gypsum observation. To the northwards the tertiary
ridge. sandstones, &c., roll over elevated ground sweeping downward into the synclinal valley, on the other side of which they are seen to rise again, the widely extended and gently curved surfaces of the naked rocks forming a fine study of contortions. To the eastward these beds curve over the edge of the synclinal and decline gently southwards to the broken and sinuous outcrop of the whole series of groups towards the fault, where the nummulitic limestone only shows itself in the escarpment as a thin and fugitive band, sometimes entirely absent. The red zone and gypsum appear below, but in much less force than near and on the ridge from which the observer is supposed to look, and the dark rock-salt, though not visible from a distance, occurs beneath all, its presence being certified by the inevitable guard tower or boorj

in the direction of the village of Tuppee (Tupí). To the south of the outcrop is the sandy bed of the upper Koshee Algod bounding a large cultivated tract in the Bárak valley (an oasis in this barren country), between the Bahádur Khél hills and the rugged lofty Sheenghur mountains to the south.

The salt at the Tuppee (Tupí) drung locality dips to the north at 30° and 40°, and shows the horizontal joints noticed at Bahádur Khél. Lying low, its quarrying is much interfered with by springs of brine. At this locality again a broken band 20 feet wide of nummulitic limestone occurs in the tertiary sandstones dipping towards and close up to the salt, the faulted junction here bending to the northwards beyond the general face of the high gypsum-covered hill to the west. In these sandstones, too, dipping northwards at 55° close to the fault, a soft coarse gray layer was observed enclosing scattered nummulites which may have been rolled, though the usual rounded lumps of limestone which occur so frequently near similar evidences of derived nummulitic materials did not accompany them. The beds near are also much contorted. Gypseous seams were here again noticed in crossing the clays of the red zone. Here, too, the overlying detrital valley beds seemed not to have escaped disturbance, a synclinal fold being seen in them close to the gypsum and gypseous clay. Under ground wasting of some of this soft series, however, may have produced the result.

At Kurruk the salt is two or three hundred yards wide and less than a mile long, but has very indefinite limits of exposure. It dips steeply to the northward, and possesses much of the appearance of that at Bahádur Khél in some beds, though clearer looking on the whole and said to be heavier.

In this neighbourhood other fault complications affect the rocks, one slip making a portion of the gypsum apparently dip beneath the salt. Another strike fault coin-

cides with a nearly east and west ravine among the tertiary sandstones to the northward, exposing a portion of the underlying series, and yet another, parallel and passing northwards of a part of this, is shown to occur by a strong rib of gypsum appearing again among the tertiary sandstones. These faults and the low cliff-like outcrops of the sandstone series about here give many opportunities of observing the disappearance of the whole of the nummulitic group, a thin representative of which is occasionally seen, and even this sometimes is entirely absent. Fig. 46 is a section across range from near Kurruk to near Rágho—

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone and clay series. F. Faults.

In Fig. 46 the Koneghurra fault, which is dying out just where the section crosses, is represented to show the character of this part of the range. The gypsum is much broken and often partially concealed, but its relations to the other rocks were made out as above. There are associated with it bands of green clay sometimes above or near the top, but generally below.

The red zone still continues, but less thick than to the west, and there are appearances of it on both sides of the gypsum in Koneghurra glen.

The nummulitic limestone has dwindled away to a few lumpy beds closely associated with the violet clay at the top of the red zone, and its junction with the overlying sandstones again shows the peculiar transition between these groups.

The lumpy limestone has its blocks separated by a sandy matrix, for a foot or two above which the sand increases, and the rock is sandstone, containing shapeless lumps of limestone, none of the corners of which are sharper than those in the limestone bed below. The lumps of limestone grow gradually smaller and fewer upwards, but after some few feet recur again in greater

quantity. Even where the limestone band has entirely disappeared, the sandy beds with limestone lumps resembling conglomerate are seen, sometimes containing *nummulites* in the matrix, and showing that these have not been derived from very local erosion of the limestone, nor does the junction of these beds with the underlying violet clays of the red zone show any sign of previous erosion or disturbance of the latter, the impression conveyed being that the limestone has tranquilly died out, sometimes leaving a couple of thin marly streaks to mark its position, and that the next succeeding beds as tranquilly took its place, the limestone lumps in these being in some cases mere nodules, indicating that the calcareous conditions had not altogether ceased, in others, perhaps slightly removed, and slightly rolled fragments conveyed by currents possibly even before the rock had acquired any high degree of hardness.

On the Andai plateau and the slopes above, the lower sandstones are thin, and here contain numerous fragments of exo-
 Bone beds: fossil tim- ber. genous fossil-wood as well as fragmentary bones and lumps of the nummulitic limestone, all of which occurring near each other are especially characteristic of the lower beds.

Eastward of Kurruk in the neighbourhood of Lukhi small exposures of salt again occur near the banks of the stream
 Lukhi salt exposures. from Turkhakooa, and not far from the fault, the existence of which is shown by the tertiary sandstone, red and gray beds dipping northerly at 45° towards the gypseous, red and tertiary series on the northern side of the stream. Here at the termination of a patch or lobe of the sandstone series the rocks are greatly broken up and cut
 Faults. through by faults, between two of which a wedge of these beds is deeply let into the gypsum. Green clays are associated with the latter, and patches of the red clay zone are rather confusedly distributed.

From Turkhakooa (Turkakúá) to Nurree (Núrrí) the whole range becomes reduced to a width of about two miles,
 Turkhakooa to Nurree. and though of no great height, the hills are so

difficult as to be barely practicable for any except foot-passengers. Fig. 47 shews the section from Nurree (Nurri) to Turkhakooa (Turkakúá) across the range, two and a half miles—

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. (4 Wanting.) 5. Tertiary sandstone series. F. Faults.

In the section the double anticlinal character of the range is again apparent in the two parallel elongated exposures of the gypsum on either side of the continuation of the tertiary sandstones which form the great synclinal to the west, this synclinal being here apparently inverted. Faults occur both at the north and south limits of the range, that to the north being a continuation of one previously mentioned as cutting off obliquely the extension of the Bahádur Khél anticlinal, and that to the south the great Bárak fault.

The Bahádur Khél anticlinal, however, does not seem to have been entirely cut off, as the curve of its southern side is continuous from Shoh to beyond Nurree. In the northern outcrop of this southern curve and also in that surrounding the Turkhakooa and Sirraikhwá gypsum, the nummulitic limestone may be said to be entirely absent for a distance of twenty-four miles, or only represented by a few thin layers of the lower part here and there of no great lateral extent, or sometimes a 3-foot pebbly-looking bed of the lower sandstone, enclosing nummulitic limestone lumps, feebly indicates places where it ought to exist.

One of these narrow layers of this limestone united by a thin band of blackish shale (such as was noticed at the base of the group in the Záwá Algud), to the violet or lavender-clay below is seen to the southward of the salt chowki or tower on the hill in which the salt quarries of Nurree (Nurri) are situated.

The gypsum of this locality seems much weathered and disturbed by atmospheric action, presenting, as usual, only unsatisfactory evidence as to its thickness and

stratification, but accompanied along its upper side by a fair representative of the red clay zone. To the southward, too, towards Turkhakooa, the gypsum sprawls over the ground with a large surface exposure from which little can be learned. The sandstones intervening between the two exposures are evidently low in the series and contain much red clay.

The rock-salt shown in the above section is not exposed at Turkhakooa (Turkakúá), but occurs to the eastward within three miles. At Nurree a good deal of it is seen forming the core of the high gypsum hill (south of the village), which is deeply penetrated by great crater-like hollows, the rain water collecting in which must find a subterranean outlet through the salt. The latter is whiter and cleaner than that at Bahádur Khél or Kurruk, and is thought to be some of the best salt in the country. Its stratification is not everywhere evident, but seems to correspond with the half anticlinal in which it occurs, and its thickness is apparently great, there being almost continuous exposures of 200 feet in the sides of the crater-like hollows, for a long distance beneath which the salt may be fairly supposed to extend.

From the salt mines hill at Nurree (Nurri) looking over the valley or plain to the north, in which the watershed between the Teeree river and Bahádur Khél streams lies, one of the finest examples of contortion on a large scale in the whole district may be seen, the tertiary sandstone series forming a wide synclinal curve, extending from the foot of the hill to the Bánnú road near Totukhi. Within this harder ridges of the sandstone are seen successively coming round by Inzurruppa towards the Speena hills, and turning back by Nurree forming a great horse-shoe bend open to the west. The character of the lower beds in the Nurree (Nurri) tributary of the Teeree Towey (Tiri Tauf), their dark red and purple colour, is distinct, while higher up in the series westward towards Rágho the prevalence of drab color among the clays can be seen even at this distance. The axis of the curve runs about 25° south of west.

At Sirraikhwá just above the village, another of the many instances of anomalous positions assumed by the rocks of the district occurs, and one not easy to explain, unless the thick mass of gypsum which here extends beyond its usual boundary and rests clearly on the tertiary sandstones be supposed either to have travelled from its place down a once higher slope, or, with greater probability, to be a recomposed mass formed from the solution of the neighbouring gypseous series, after the manner, somewhat, of calcareous tufa. The appearance presented is figured below :—

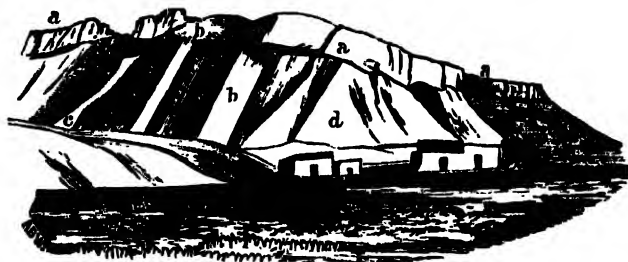


Fig. 48. Gypsum above part of the village of Sirraikhwá (Hirraikhwá) looking east.

a. Gypsum. b. Tertiary sandstone clay. c. Red clay (? the red zone). d. Débris. e. Green clays under gypsum, close to supposed place of fault.

Close to where this occurs is the place of the Bárak fault, and the red clays *c*, may possibly be those of the red zone, which it is hardly possible to identify in some situations where nummulitic limestone is absent.

The Sirraikhwá reputed old salt quarries are situated not very far from this spot on the higher ground above the village, surrounded by masses of gypsum and gypseous *débris*. At the western exposure the salt has a surface exposure of about 35 feet in height, thickly covered on top by *débris*, the beds dipping north at 40° and 50°, and the salt having very much the character of that at Nurree (Nurri). Nearer the Sirraikhwá *boory* there are three subsidences, one being a large double pot hole or crater-like hollow, indicating the removal of salt from below. Close by there rises

a conspicuous hill, much of which is made of salt having a low dip to the northward of east, and showing oblique lamination in such a way as to indicate that the deposition took place from the northward. The hill shows a section of nearly 200 feet in the salt, to which must be added the unknown quantity shown by the occurrence of the craters to have suffered subterranean erosion. This hill is capped by gypsum, with a

Gypsum passing into red zone.

15-foot band of green clay towards the top. The gypsum passes by thin alternations into the succeeding red clay zone, and resting upon this without a vestige of the nummulitic limestone or the lavender-clay intervening, is

Nummulitic limestone absent.

a strong escarpment of the lower purplish tertiary sandstones, the stratification of which at the junction appears somewhat irregular, but not sufficiently so to warrant any assumption of unconformity, although the basal beds sometimes contain the usual limestone lumps. These sandstones conform to the narrow anticlinal easterly ending of of the Sirraikhwá gypsum, their inclinations approaching the vertical

Tertiary sandstones.

near the apex of the curve. Some grayish sandstones forming the upper beds of the escarpment abound in fossil, apparently exogenous, timber, a gnarled, knotted, and once branching trunk which lay prostrate, weathering from the rock, being found to have a length of 20 feet, while slightly separated portions of it were traced for 40 feet further.

The ground north of Tubbaikhwa formed of sandstones and clays

North of Tubbaikhwa.

immediately succeeding these, is extremely bare and rocky where traversed by the pass of Kohneega (Kohníga) to Nurree (Nurri), a large space being occupied by a group of bright red clays which, with the associated sandstones, are intensely contorted and crushed in the region of the Báruk fault.

These sandstones and clays form a continuation of the series of the

Continuation of central synclinal.

great central synclinal of the rangg to the westward, no longer recognisable here, for the beds over the axis of the narrow Sirraikhwá anticlinal and along its northern

side are vertical, rising like a wall, with one very conspicuous peak, between this sandstone and clay ground, and the wide gypsum expansion of Speena (Spína) to the north (called Ispeenha on the map).

This large exposure of the gypsum occurring within much narrower Speena (Spína) gypsum limits on either side is apparently a resultant of tract. complex thrust and resistance to the contorting forces arriving at this place from different directions, one of the most powerful impulses coming apparently from the westward in the direction of the great synclinal curve occupying the low ground at Nurree (Nurri,) and perhaps influenced by special lines of weakness, which, so to speak, diverted the Nurree (Nurri) fault to the north of this gypsum tract.

The latter is enclosed on all sides, save where the gypsum continues Bounded by vertical from it, by vertically bedded rocks with a tendency strata. along the northern side to inversion; within these the gypsum rises covering heavily undulating ground traversed by deep nullahs; its want of variety and contrast to the sharply serrated adjacent sandstone and clay country being evidently produced by the homogeneous nature of the rock, the white colour of which has The gypsum. given the place its Pushti name, though veins of reddish and yellow colour also occur. Most of the rock is naked, but there is an inclination among the water-courses to silt themselves up, thus forming lakes or small alluvial hollows, and where there is any soil, it is said to be the most productive in the country.

Lakes or "dunda." A large pond or 'dund' exists in one of these hollows, having no escape unless there be some subterranean exit, and a fabulous reputation for the coldness of its water. In the bed of another, which had evidently found a way to drain itself by a stream course now traversing the spot, small dead *Planorbis* like shells and the fossilized stems of marsh plants converted into yellow carbonate of lime were found embedded in a stratified gray sandy clay. The latter attracted attention by their numbers and the startling resemblance of their cylindrical forms to Belemnites.

* Towards the higher parts of the gypsum ground, large, circular, or elongated spaces seem to have fallen in forming Speena (Spína) salt. deep hollows, in which a great quantity of the underlying rock-salt is exposed, its stratification being either horizontal, or gently undulating, and conforming to the clays and gypsum above. At one place here a 15-foot band of gray and reddish dark-mottled clay intervened between nearly horizontal gypsum and a 50-foot exposure of the rock-salt below. Not far from this the gypsum contains scattered crystals of iron pyrites. Some of the large salt exposures here were estimated to have a depth of more than 200 feet; they lie chiefly at the north-west side of the tract, and send a copious supply of the mineral in solution to the streams below, as shown by the quantity of 'shor' visible in their beds.

The red zone is here chiefly visible from the color of its débris around the outer limits of the gypsum: along with Red zone. it at the western side of the latter a few beds of gray sandstone, much like those of the tertiary sandstone series, were observed which might have been a local development of its upper sandy layers, but everything about the place was so much disturbed, that these might even have belonged to the higher group here let in by faulting.

On the northern side of this Speena gypsum and red clay zone the nummulitic limestone re-appears as a narrow, vertical band bending also round to the west and southward till suddenly cut off by a fault in the pass of Kohneega (Kohníga). It is much disturbed and slipped in places, one vertically bedded mass having been observed separated by an inclined slippage plane from likewise vertically bedded tertiary sandstones on which it rested. Further west, on crossing it from the Speena (Spína) salt exposures to Nurree, its lower layers were found to be earthy, containing only obscure spiral shells and the main mass of the *alveolina* kind; while the uppermost layer of all was a limestone conglomerate, the pebbles or lumps in which were mostly of limestone as Limestone conglomerate. was also the base, the latter containing *alveolina*.

In the pass of Kohnneega (Kohníga) at its narrow northern opening the confusion of the rocks is extreme. The salt is seen above its eastern side amid a crushed mass of the clays of red zone, on which detached fragmentary masses of gypsum rest. The latter on the west side of the pass has a thickness of 100 feet, dipping steadily to the east of south at 60°, succeeded by the tertiary lower sandstones with a higher dip of 70°, in the same direction and some traces of the red zone between. The limestone comes from the north-eastward perfectly vertical, but just where it ends is doubled partly back upon itself, increasing its apparent thickness to nearly 100 feet, and in its general strike on the west side of the pass a small mass of the limestone is crushed in among vertical tertiary sandstones faulted against the Nurree (Nurri) gypsum. The vertical and highly tilted bedding of the latter soon gives place to more moderate dips as the beds pass gently beneath the Nurree (Nurri) synclinal.

Northward of the Speena (Spína) gypsum tract the whole valley, across to the Bánda hills, is occupied by a perfect tertiary sandstone basin of Sháh Báz Ghur. quaquaversal basin in the tertiary sandstones little less in size and more complete than the Nurree (Nurri) feature. In the very centre of this a tabular mass of the sandstones edged by mural precipices rises considerably above the neighbouring country forming the picturesque site of the ruins of Sháh Báz Ghur. Within this basin the gray sandstones and red clays have the appearance of the middle rocks of the series, and in the stream course beneath the hill on which the ruins stand numbers of crystalline erratics from the upper conglomeratic beds of the series were found, whence it may be inferred that these also once overspread this part of the country.

An isolated and elevated trough of the lower tertiary sandstones, nearly of the same size as the Speena (Spína) gypsum tract, occurs to the eastward, forming the upper portion of the mountain, summits of which are called Muzdukkai Sír and Kurar Sír.

The eastern side of this trough is a simple synclinal, but to the west at the narrowest part of the whole range the curve is overthrown to the south. The section, Fig. 49, is taken nearly midway between and shews a length of about two and a half miles.

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstones.
6a. Beds towards upper part of same series. F. Bárak fault.

The nummulitic limestone is absent or but slightly represented to the west of this synclinal, but to the east is largely displayed from its position more than from its thickness. The red clay zone is seen beneath where not interrupted by faulting, the gypsum occurs below, and the rock-salt is locally largely exposed to the south, in the escarpment of the mountain below the summit of Kurar.

An interesting but complicated section is exposed in the *Algud* which crosses the range running northward in a deep ravine between the Kurar synclinal and the Speena (*Spína*) gypsum tract. Descending this ravine from near Shaidan, tertiary, red, and gray sandstones and clays are passed through, dipping southward at 70° or more nearly vertical. Red clays of the red zone with a thickness of 150 feet underlie these, or would, if there was any underlie to speak of. Gypsum, nearly vertical or dipping at a very high angle to the south, 155 feet thick, and with greenish clays on both sides, is then passed. In the lower part of this gypsum the southerly dip lessens to 60°, and the beds are contorted. A few yards further on apparently the same mass of gypsum, curved and undulated, seems to increase enormously in thickness up to 300° or 400 feet, 30 feet of its lowest part being dark or black and bituminous calcareous shales (see analysis No. 2, page 48). At this place sulphurous springs break out at the sides of and in the *Algud*, the whole place smelling strongly of sulphuretted hydrogen. For several yards further, disturbed and partly inverted gypsum is seen, and then the red clay zone is entered with a local appearance of large thickness. Its red sandstone bands near the top are also largely

developed, but irregular, and a layer of these from 3 to 4 feet thick is quite black, heavy, damp-looking, and smells so strongly of petroleum that it might be found with one's eyes closed.

Bituminous sandstone
in red zone.

A few bands of brownish red clay intervene between this and the violet clay band above, immediately over which the nummulitic limestone comes in rather strongly, with an apparent thickness of 50 to 75 feet, vertically bedded, but its cross section, as is often the case, inaccessible for measurement.

On the basal surface of one of its lower beds groups of stars, at first looking like clusters of coral, were observed. On closer examination these were found to consist of a whitish mineral, in radiating prisms, some of which, on being tried by Dr. Warth, gave the red flame of strontian before the blowpipe.

Mineral in limestone.

Beyond the limestone to the north the lower tertiary sandstones were seen to succeed it, and another rib of this limestone brought up by disturbance occurs among these further northward near Krunzeenai (Krunzínai).

Ascending the left bank of the Álgud, gypsum and gypseous débris only were observed, hemmed in on the north by a limestone rib, with traces of the red zone at its base, and on the south by the lower tertiary sandstones and clays, but above the opposite bank the distorted synclinal admitting the last named beds was seen; the section being confused here and there by slippage of different portions of the rocks on the steeply sloping hill side. See Fig. 50, which is a diagrammatic sectional representation of the rocks on right bank of Álgud near Lakkona and of Muzdukkai hill looking east.

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c.
a. Greenish clay. 6. Petroleum impregnated sandstone. c. Débris.

Down in the ravine it is not clear how the beds are arranged, but from above the Speena gypsum is seen to divide into two bands, each

taking the opposite sides of Muzdukkai hill. From the general arrangement of the beds both of these bands appear to have filled the interiors of anticlinal curves, the positions of which were altered by lateral pressure and their ordinary relations obscured by faults.

In the bed of a deeply cut ravine from the Kurár mountain escaping from its northern side near Nishpo, at a place called Z'murree (Z'murri) Thang (or tung), one of the very frequent constrictions of the gorges as they traverse the nummulitic limestone occurs, leaving, indeed, no visible passage except that for the water of the stream through the vertical wall of limestone. A precarious footing may, however, in one place be found overhanging the deep pool below, around which the rocks are all exposed.

Here some beds of the limestone are most strangely placed, the upper layers being apparently intercalated and dovetailed with the lower beds of the sandstone in contact after a manner that cannot be altogether attributed to crushing or pressure, and would seem fatal to the idea of unconformity between the groups. Fig. 51. shews this section at Z'murree (Z'murri) Thung waterfall.

Alternation of limestone and lower tertiary sandstone.

2. Gypsum. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone.

The band of limestone marked (c) continues up the right bank of the ravine, but seems to have thinned away on the left bank; the intermediate reddish purple clays and sandstones apparently thin out to the east, but contain calcareous layers (a) and (b), which as well as (c) contain *nummulites*, the upper band (c) being of a gnarled, lumpy, mixed, sandy, and limestone nature.

The mass of the limestone at the waterfall is locally thin and of the hard *alveolina* variety, and the red clay zone and gypsum come in immediately behind it. Over the surface of this gypsum small fragments of magnesian limestone layers evidently associated with it were observed, and the limestone was seen again edging the southern side of the gypsum.

Magnesian limestone associated with gypsum.

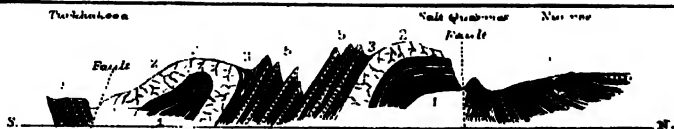


Fig. 47. Section from Nurres to Turkhakoon



Fig. 48. Section across Kurar mountain



Fig. 49. Diagram of rocks on the above right bank of Lakona gully

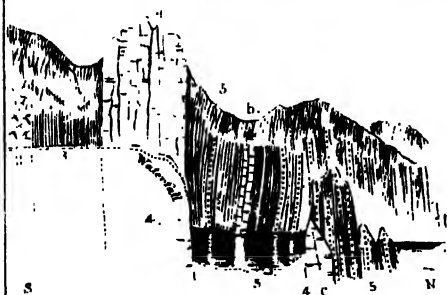


Fig. 51. At 15 miles-thung waterfall



Fig. 52. Oblique termination S. of Jona Kollakhet



Fig. 53. Section down the Mitan Pass



Fig. 54. Section from Zertung to Shukurdurra Plain

To the north of this place in the neighbourhood of Sundá Kulla-Khél, the tertiary sandstones undulate in wide curves over the ground, but dip steeply to the south in the banks of the Teeree Towey (Tírfí Tauf) river. Red clays are largely associated with the gray sandstones towards the hills southwest of the above-named village, forming a large anticlinal curve in the direction of the axis of the Sháh Báz Ghur basin. Where this curve is crossed by the deep Álgud from the Lákkona ravine, much irregularity of deposition was observed at one place on a sufficient scale to have been mistaken in a smaller exposure for unconformity or overlap. See Fig. 52.

The Kurár salt locality on the southern side of the hills is a very large exposure in the lower part of the cliff, in which the faulted and apparently rugged surface of the salt has been so clearly pressed against the sandy clays and incoherent sandstones of the adjacent middle portion of the tertiary beds that portions of these have been left as it were inserted between the salt and gypsum as well as entangled along the outcrop of the salt.

Above the gypsum the red clay zone and nummulitic limestone are seen in the escarpment, the top of which is formed by lower tertiary sandstones, the nummulitic band at one spot appearing twice, separated by over 150 feet of the former, as if a portion of the escarpment had slipped downwards.

The salt, of which fully 150 feet is exposed, is here exceptionally pure, having less traces even of intermixture with blue clay than usual, and the upper beds, as at Jatta and several of the eastern localities, contain black bituminous bands.

The pale, bluish-gray, micaceous sandstones, with many alternations of bright red clay, have a very soft texture, and appear to belong to the upper rather than the lower portion of the tertiary sandstone series, brought into this place by a

continuation of the Bárak fault. They strike pretty steadily east 20° north, and are either vertical, or dip at high angles from the hill.

To the eastward of the Kurár synclinal, which is here much more simple in its structure, the nummulitic limestone forms a large sheet conforming to the curve, but most exposed at its southern side lying between the two bands of gypsum embracing Kurár mountain. Owing to some irregularity of the axis of the curve, the limestone sinks comparatively low to the north of Dund, a village which takes its name from a small rushy lake without an outlet situated in this low ground. An east and west fault is believed to pass just to the north of this little lake separating the limestone from a long rib of gypsum, between which and this limestone tertiary sandstones, also believed to be faulted, come in to the east.

In this direction also, within a couple of miles of Dund, the other (southern) gypsum zone rises as the adjacent river falls, till it becomes a lofty mass closely flanked by the sandstones, &c., to the south, contorted, nearly vertical, or sloping away from it. Upon this gypsum the red clay band rests, and is succeeded by the limestone, while in the southern face of the gypsum itself are one or two small exposures of the rock-salt.

One of these is called Durvee or Durree drung, situated at the bottom of a deep ravine in the gypsum; but little of the salt is seen, and this shows a northerly dip.

The gypsum above is much disturbed, and often covered with its own debris, or that of the red clay zone, sometimes appearing as if enclosed within it, or caught in contortions.

In the sandstone layer of the latter band there occurs here a purple and green gravelly-looking finely concretionary hæmatitic bed only worth noticing as it may

possibly indicate the source of the Wuzereee (Wazírí) iron imported from that wild country lying to the westward of this district.

The overlying limestone is contorted and disturbed, rolling over the hills with a preponderance of northerly dip.

The ridge formed by this gypsum and limestone soon declines and disappears, but the range is carried on eastwards by two others from Kurár mountain, one of which to the north, called Zyaruttí páhár, shortly becomes separated from the intervening ridge by a considerable rugged and rocky central valley. This Zyaruttí ridge, like many others of the country, is a half anticlinal, the other half having disappeared in a long fault at its southern base. At its western end the anticlinal just overturns the axis, the limestone being followed round by fine bold rocky outcrops of the tertiary sandstones. Close to the eastward of the summit the arrangement is somewhat disordered by a cross fault which clearly lets down a mass of the sandstones below the limestone level. From this to the interruption of the ridge at the Mittán pass the relations are normal, the gypsum, red zone, nummulitic limestone and sandstones, &c., succeeding each other, but towards the pass the limestones come more across the axis tending to complete the curve, while the southern or gypsaceous slope is, as usual, smooth or overshot by débris, and fails to expose the rocks as they project on the crest and northern side.

In the gypsum area nearly beneath the summit are two small (reputed) rock-salt localities. This Zyaruttí hill commands a fine view of the neighbouring country and the Suféd Koh and other Afghán mountains rising behind the Affreedee (Affrídí) hills. Its section, however, does not seem to present anything remarkable, except that towards the lower half of the nummulitic limestone, there are some of the white softer marly beds abounding with the usual fossils,

among which the rough *Gryphaea*-like form alluded to as characteristic of this Trans-Indus nummulitic rock is conspicuous. -

The Mittán Turtullí, or (as the natives call it) Turrilla, pass, is the bed of a deeply cut ravine, the stream of which is formed by the collection of several others from the Lukkur Ghur mountains and the south side of Kurár, the most important ones uniting near Dund. The stream thus formed is one of

the numerous examples in the country of its main drainage bearing little relation to the disposition of its ridges, these latter being crossed in various places by every considerable stream in the district. Following the river through the Mittán pass

towards the Teeree Towey (Tíri Tauí), the red clays and soft gray sandstones seen from Kurár to the end of the Dund ridge are found to dip at high angles to the south, becoming vertical just at the latter spot. The Dund limestone of the left

bank is cut out by a fault, and behind, or immediately northwards, lower, purple and gray tertiary sandstones, &c., are also highly inclined to the south. Crossing these for

more than half a mile, they are again suddenly faulted against a mass of gypsum with some traces of an anticlinal structure, this being the gypsum of the central ridge and a continuation of the northern band of Kurár. The red clay zone makes no great show here on account of its softness, but is, as usual, present in inverted order overlying 250 feet of the nummulitic limestone, the back bone of the ridge, which likewise overlies, at angles of 65° and 70° to the south, a long series of steeply inclined or vertical beds belonging to the lower tertiary sandstone series.

Another fault still cuts these off from the gypsum of the Zyaruttí ridge, on the northern side of which the limestone and lower tertiary sandstone lie in their proper order as shown in Fig. 53, a section through the Mittán pass, about three miles.

2. Gypsum 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone series, lower. 5a. Ditto, upper.

To the north of Shukkurdurra (Shakkardarrá) near the base of the central ridge which there becomes the southern side of the range, the continuation of the Bárúk fault produces for some distance a very confused state of the rocks along a narrow zone. Here fragments of the series, chiefly of the limestone and gypsum, are wedged in a most complicated manner into tertiary sandstone series without relation or order, but when of any considerable size from their difference of texture showing themselves distinctly among the adjoining beds.

On the ridge above the gypsum is extensively seen bent into large curves recognizable by flaggy layers, which near the top alternate with the red clays and have rough, ripple, or current marked surfaces. Above the red zone comes the limestone, often vertical, but sometimes showing well marked portions of the northern side of an anticlinal arch, or complicated slippage bringing it (out of place) over some of the adjacent beds. It here again contains the peculiar *Gryphaea*-like shell before mentioned, and several other nummulitic forms, none of which have been as yet examined for determination.

From this the descent into the Wudda Brugdai valley is over the lower tertiary sandstones, &c., which in this rocky glen are much disturbed, sending faulted bands among the hills to the east and one compressed synclinal curve to the north-east. In the latter, down which drainage of the valley largely escapes, there are at no great height in the group apparently some greenish-gray soft sandstone layers containing the usual assemblage of fossil bones and exogenous wood.

The northern side of the valley is shut off from the Teeree (Tírf) gorges below Kureerosum (Kurírosum) by an extension of the Zyaruttí ridge, here forming the northern side of the range. On the inner slopes of the hills there is much gypsum seen, succeeded by the red zone and overlaid by nummulitic

limestone distorted in places, but on the whole continuing the zyaruttí half anticlinal, the uppermost beds occurring on the northern side, except just

Anticlinal. south of the Saya (Séya) Malgheen salt quarries (Málgín), where both sides of the anticlinal curve

are visible, the inner one coinciding with the northern side of the tertiary sandstone synclinal at the outfall of the valley.

From this place to the south-eastward the whole range from side

Complicated repetitions of beds to east. to side is formed of ridges exhibiting complicated

repetitions of all the groups from the tertiary sandstones downwards to the gypsum, below which even the salt itself appears as at two places, one near Peer Ghoot (Pír Ghút) Sír to the north, the other near the village of Kuroree (Kurorí) to the south.

A general view of this ground may be obtained from the narrow limestone crag which forms the summit of Ghozheyreen Sír (so called

Ghozhayreen Sír. upon the map, but in the native Pushtú gutturals sounding as nearly as could be imitated by the

English letters Wgh-jeer-eeen-a, the first syllable forming a single sound) See Fig. 54 shewing the section across range from Zertungí to Shuk-kurðurra (Shakkardarra) plains.

1. Rock-salt. 2. Gypsum. 3. Red zone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c., lower. 5 a, Ditto middle. F. Faults.

From this peak, too, the whole of the harder rocks of the range may

Great cross fault to east. be seen cut off to the east by a north north-west

south south-east fault, all the different groups running straight at and against an exposure of gypsum between two and three square miles in area. To the south-east also a patch of the nummulitic limestone, likewise faulted, is seen near Nundrukkí village, and the whole place appears to be another focus of faulting and disturbance, by the united agency of which the harder bands have been so placed that the

Change in direction of range. range, instead of terminating as others do, is suddenly deflected nearly at right angles to the

southward, accompanied by such contortion of the beds, in large compressed curves, that a length of outcrop equal to eight miles is

forced to occupy a space between two points only four miles apart from north to south of the Húkaní mountains.

In the wide area of gypsum just mentioned, and which is bounded by a thin disturbed band of nummulitic limestone and adjacent strata, the salt locality of Nundrukki is situated, the guard tower marking the spot where the largest exposures occur. These are all situated in great crateriform hollows sunk among rolling gypsum-covered hills and receiving a considerable quantity of the local drainage by deep ravines, the streams disappearing subterraneously into dark caves in the salt to find an exit no person can tell where.

The salt is of the usual gray colour, and undulates with a northerly inclination; it shows cliff faces of 60 feet in depth, and, from different levels of the exposures, may have a thickness of more than 150 feet.

The gypsum rises into rounded and many channelled hills intersected by deep ravines; much of it would appear to be recomposed on the surface containing a large admixture of reddish clay or earth, probably débris of the red zone, as well as fragments embedded of the nummulitic limestone enclosing fossils, and of the tertiary sandstones in a tender semi-crystalline base, sometimes containing small bipyramidal crystals of quartz and little crystalline fragments of dolomite. Some of it is black with or without the usual petroleum smell of these dark portions.

The red clay zone is best seen on the higher situations beneath the nummulitic band of Qund Húkaní (the widower's peak), but in lower places, where the gypsum rises above it, concealment often results both of this and, in places, of the limestone band. From the northern eminences on this rolling gypsum ground the contortions of the tertiary sandstone series in the Teeree Towey (Tíri Tauí) valley are very conspicuous, the dark purple and red lower

Contortion in Teeree
Towey (Tíri Tauí)
valley.

beds rising boldly over the axis of the Malgheen (Málgín) salt quarry ellipsoid, the synclinal hollow in which the Teeree (Tírí) river flows being filled with smaller anticlinal arches and synclinal curves, while so rocky is the ground, that each bed might almost be counted. At a short distance to the east, these smaller contortions disappear, and the beds sweep round the eastern end of the wide gypsum expansion, at the same time rising towards the rugged crest of the Húkaní hills.

Between Nundrukki boorj and the summit of Sookawar (Súkawur)

Hokunní (3,170+70 feet=3,240 feet) a substratum of gypsum is covered by a broken crust of

nummulitic limestone, in some places almost appearing to be *in situ*, as if large masses of the adjacent outcrop had here settled into a horizontal position. The very summit of the mountain is a narrow vertically bedded east

Sookawar Hokunní and west crag, towering above everything else in summit.

its neighbourhood, seen from the north appearing as a hog-backed rise, but looking like a huge obelisk when viewed in the direction of its length. Around the crag, great fragments of limestone are piled, sometimes of the size of houses, and on its slippery apex there is barely room for three or four men to perch themselves. Looking from here, the compressed and very steeply inclined folds of the limestone are seen followed within by the red clay zone and pro-

The surrounding coun- jections of gypsum, and outside by the lower beds try.

of the tertiary sandstone series, plunging down below the valley of a deep sandy bedded nullah tributary to the Teeree Towey (Tírí Tauí). Beyond this nullah the long horizontally stretching outcrops of the middle beds of the same group sweep round the opposite hills, slightly inclined from the spectator, all the upper part of these hills showing for a great thickness the peculiarly billowy, fretted, and mammillated surface, produced by the rapid disintegration of the soft glistening sands of the upper part of this great tertiary group, extending thence to the Indus above Mokud.

In the opposite direction overlooking the Shukkurdurra (Shakardarrá) plain the outcrops of the tertiary beds are seen displayed as if drawn upon a map in bold open curves, which look all the more striking as minor undulations are lost sight of in the distance, the nearer beds showing converging southerly dips as far as the strongly marked mural escarpment of a great patch of these sandstones in the vicinity of Hussunshood (Hassanshúd) which shows a gentle inclination to the north from the slopes of the Lukkur Ghur mountains.

Descending from Sookawar (Súkawa) Hokunní to Shukkurdurra (Shakardarrá) in crossing the outcrop of the gypsum, there were found associated with its upper part a 3-foot band of compact gray limestone overlying and indeed intercalated in gray, highly gypseous 'Sheenkoura' shales with limestone layers. The whole group, including the thick gray shales and some gypsum bands below, has a thickness of 25 or 30 feet, exclusive of the main gypsum beneath, which is much concealed by débris.

These limestones were closely looked to for fossils, but nothing could be found except a fragment of an *oyster*, an imperfect cast of a small *bivalved shell*, and a few other shell fragments, all too indefinite to expect that they could be determined. The limestone, however, has much the character of some basal beds in the nummulitic series, and also resembles beds found occasionally in the gypseous portion of the Potwár Subáthu rocks.

These indications of themselves are all too small to build any argument upon, but taken together with other appearances, help to fix the idea that the gypsum at least, and possibly the salt as well, form part of an extended nummulitic succession.

The tertiary sandstones and clays of the Shukkurdurra (Shakardarrá) plain have little to distinguish them from the great bulk of this gray and red series. They

certainly have not much the look of the lowest beds, and many of the sandstones are soft, yet the preponderance of alternations of reddish or red clay and light gray fragile sandstones prevailing westward, near Kurár mountain, is not marked here, owing perhaps to superficial concealment of all but the hardest of these soft sandstones.

There is something in the incoherent nature of the sandy parts of

the superficial covering, the local flatness of the

Quicksands.

ground, or the disposition of subsoil drainage that tends to produce quicksands (having doubtless an exaggerated character as to depth) along the margin of a sluggish stream which passes through the village of Shakkurdurra (Shakkardarra). These are small circular patches in the damp ground where the hard rushy surface is suddenly converted into liquid sandy mud, perhaps kept moist by the presence of little springs. No stick could be found long enough to sound one of these, and their dangerous softness was said to vary at different seasons.

For four miles southward of Shukkurdurra (Shakkardarra) the

Newer tertiary beds
south of Shukkararra.

harder strata project in the form of small hills, parts of contortions showing steep dips to the north and south. In this country, too, the hard crystalline pebbles from the newer beds of the series are strewed over the ground; these increase in quantity, ascending the bed of the stream which passes by Hussunshood (Hassanshúd), but it is not until close to this place that the soft gray sandstones are found to contain some small pebbly strings. Further south they increase in quantity on the surface to the exclusion of soil or anything else, thickly sheeting the ground and forming, as is their usual habit, smoothly dressed gentle slopes. Yet even here no strong bands of conglomerate are found from which they might have been derived.

Within a mile south-westward of the above-named village, a rugged

Craggy hills near Hussunshood (Hassanshúd).

group of hills is reached at a place where 'perpendicular sandstones' is marked upon the map,

but this description only applies to their precipitous sides, the beds themselves being very thick, soft sandstones gently dipping to the north, or more nearly horizontal. In these beds there are again, but rarely, small conglomeratic layers with the same quartzite, syënite, and other crystalline pebbles as strew the neighbouring ground, of much smaller size and wholly insufficient to account for the quantity of the latter. Some dark gray shale bands also occur at wide intervals, and one peculiar orange layer of ferruginous clay is seen near the base of the cliffs. The sandstone is coarse, minutely specked with white atoms, micaceous and homogeneous, weathering into fantastic crags, one of which is perforated so as to look exactly like an artificial '*chhappar*' or shed. One peculiarity of these cliffs is that they show in places a steeply sloping talus, in which there would be nothing strange if it were

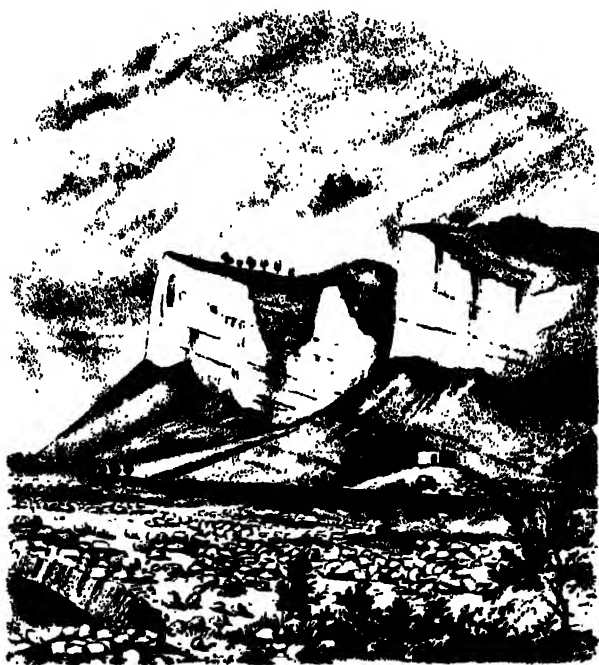


Fig. 55. Upper tertiary sandstone cliff near Hassanahéd.

formed of *débris*, but it is instead a portion of the solid rock of the escarpment smoothly worn, and even at its junction with the vertical cliff simulating the arrangement of detrital materials, as seen in the figure (Fig. 55), of the upper tertiary sandstone cliff near Hussunshood (Hassanshúd).

The rocks are here so frequently seen, that any large stratum of conglomerate would probably show itself, so that the numbers of smooth, rounded, hard boulders and pebbles about may either be supposed to have come from one of the thick conglomerate zones of the northern side of the Sheen (Shín) Ghur range (as shown in Colonel J. T. Walker's section map No. 3, Northern Trans-Indus Frontier Survey) continued to the Lukkur Ghur, or to have remained the most indestructible parts of former conglomerates which had once existed over this ground.

ECONOMIC RESOURCES.

The economic resources of this district are principally its enormous deposits of salt, which, being of great importance, are treated of under a separate section appended hereafter.

Salt.

Large as these salt deposits are, the quantity of gypsum in the district is probably still larger, even though appreciation of this be partly due to the greater display it makes over the district on the sides of, or within the hills. But the advantages to be derived from the use of this mineral in agriculture or the arts are apparently entirely unknown, and it is utterly neglected. In other countries it is mined for; here it could be obtained in any quantities at day-light. On the large expansion of the gypsum, &c., at Speena (Spína) the crops (particularly the wheat) are said to be better than in any other part of the country, yet the natives seem never to have drawn the inference that it would be useful as a manure.

Gypsum.

The sulphur pits at Gunjully hills, close on the northern limits of this district, have been already mentioned at page 99. From the way the alum shales have been burrowed into, much of the best part of the deposit may have been exhausted just at that spot, but there is no reason to suppose that it has not some extension beneath the neighbouring débris. It is on record (see foot-note to page 99) that 1,000 maunds of sulphur used annually to be won here, and it seems strange that the deposits are not now utilised as a source for the supply required at Láchee (Lachí) for the blasting powder manufactory where all the powder used in the salt quarries is made.

Sulphur.

There can be little doubt that the alum shale deposits mentioned in the foregoing pages would, if the manufacture was tried or encouraged, afford alum in the same way as those of the Chíchali pass to the south.

Alum.

There are several varieties of rocks in the country which would afford excellent building stone. Among these the nummulitic limestone would probably take the first place, and as there is considerable variety in the texture of its beds, it may be supposed that ordinary requirements would readily be met.

Building materials.

The harder bands of the gray and purplish slightly calcareous sandstone of the lower tertiary sandstone group are elsewhere very generally used as building stone, and would doubtless be found equally useful here. Mixed with the lighter coloured limestones they would produce a handsome variety of tints for ornamental 'ashlar' work, and among the most thinly stratified layers serviceable flagstones could probably be obtained.

The limestones furnish lime, the gypsum would furnish plaster of Paris, the clay of various places is convertible by burning into 'soorki,' and there are occasionally to be met with in the Kohát district earthy limestone layers near the base of the nummulitic limestone which might furnish hydraulic cement.

Cement materials.

Since the previous pages were written, intimation has been received of coal having been found on the borders of, if not within, the district under notice.

Coal.

By whom it was discovered is unknown, but its being brought to notice is due to a native officer of Kohát station and to Major MacLean of the Frontier Force.

It appears that the native officer when on leave heard of the existence of the coal near certain cliffs situated at some distance southward of the village of Dand, north-west of Shakkardarrá. He had great difficulty in finding anybody willing to show him the spot, and though, when he reached it, without any digging implements, he succeeded in extracting some baskets-full of the coal.

He could give no information as to the thickness of the seam, and could only say it occurred in a sandstone cliff.

The coal is described as bright, and to all appearance good, and the situation indicated for it is among the upper beds of the tertiary sandstone group, where thin layers of lignite and fossil-wood converted into coal are not unknown in other parts of the country.

At the time the examination of the district was in progress, places in the vicinity of the locality where the coal is said to have been found were visited, but of its existence nothing whatever was heard, probably for the same reasons, whatever they may have been, which made the people of the neighbourhood anxious to conceal it from the native officer.

From the position of this coal it seems unlikely to prove of much (if of any) economic importance. Coal or fossil-wood embedded in these tertiary sandstones is often bright and good enough, but totally deficient in quantity, yet there is no reason why a workable, though perhaps not extensive, coal bed should not exist among them.

Specimens of the coal are promised for transmission to Calcutta, and further enquiry will be made about the matter.

Since writing the former note further enquiry has been made, and Captain Cavagnari, Deputy Commissioner of Kohát, is of opinion that the Dánd or Dhand village alluded to is not the Dánd near Shukkardarrá, but the village of Shín Dhand in the country of the Jawakí Affrídís, a place not marked upon the map, but situated probably near the Jawakí (or Zhuwakakí) pass, crossing the eastern part of the Affrídí hills, projecting into British India between the Kohát and Peshawar districts.

It is not quite certain whether this may be the situation of another coaly bed; if coal exists there, it is probably a continuation of the carbonaceous alum shale zone which occurs on the north side of the Nilab Gash hills, near the village of Nummul, intersected by a stream which falls into the Indus from the right bank below 'Ghoratarap' (the horse's leap), where the stream is said to be only 60 yards wide. This alum shale is thought to be jurassic, or lower nummulitic.

A. B. W.

PART III.

EXTRACTS FROM REPORT,

*On the economic aspect of the TRANS-INDUS SALT REGION, by
DR. H. WARTH, Inland Customs Department.*

With additions by A. B. WYNNE, Geological Survey of India.

Index to Part III. On the economic aspects of the TRANS-INDUS SALT REGION.

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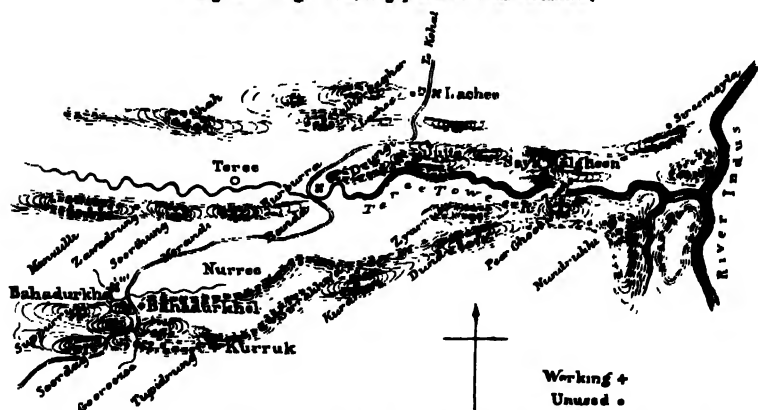
PART III.

On the ECONOMIC ASPECT of the TRANS-INDUS SALT REGION, by DR. H. WARTH, Inland Customs Department, being extracts from the report submitted to Government ; with additions by A. B. WYNNE, F.G.S.*

The position of the salt region and the rocks found associated with the salt have been already described in foregoing parts of this memoir, and it has been mentioned that the salt quarried at Kálábágh, although situated on this side of the Indus, from its character and geological associations, is to be referred to the saline deposits of the Salt Range, rather than to those of the Kohát district.

There is a wide difference in the manner of working the salt of the Cis and Trans-Indus deposits, the former being all obtained by underground mining, while here mere quarrying is the rule, notwithstanding which, the name of 'Kohát salt mines' is often applied to the Trans-Indus salt quarries. For facility of reference the following sketch will show the relative positions of the old and modern salt quarries or localities in which the salt is now worked, as well as places where it is known to exist.

Fig. 56. Diagram shewing positions of salt localities.



* This report of Dr. Warth in full was forwarded to and printed by order of Government. Some additional historical particulars from Captain Flowden's memorandum are added here.

The quarries which are now open have been worked for a very long time: the Jatta quarries since 1650, and those at Malgheen (Málgín) from time immemorial, while those at Bahádur Khél are said to have been originated twelve centuries ago.

The following historical details are taken from Captain Plowden's memorandum (of 1872) already noticed:—

"Jatta is said to have been so called because it was first colonised by Jats, but it is now inhabited by Khattaks. When Khushal Khan, the warrior-poet, Khan of Teeree (Tírf), the bravest and most learned of his line, came to Teeree (Tírf) from Akora (about A. D. 1650), the salt was first quarried and sold for seven bulluck-loads per rupee to Bangashes and Affrídís, and twelve loads to Khattaks.

"Malgheen (Málgín) is so called from the Pushtú word malga, or salt; from time immemorial its quarries have been resorted to, but Sháh Báaz Khan, Khan of Teeree (Tírf), A. D. 1780, was the first to make it a source of income. The Khans of Teeree (Tírf) and the villagers of Malgheen (Málgín), Dur Tappee (Dur Tappí), Dorshand, and Kuree-rosum (Kurírosum) have ancient proprietary rights therein.

"Nurree (or Narí) is said to be so called after one Narraí, who first settled here. He was succeeded by the Khoji Khél section of the land clan of Khattaks. They roofed their houses with branches of the Pullosa (Phúláhí?) tree (*Acacia modesta*); hence their village is also called Pullos (Punnose? on map). Its salt hills were first generally resorted to in the time of Sháh Zaman Sháh, Saddozai of Afghánistán (Circa 1800 A. D.) The Khuji Khéls are the proprietors of the soil and reside in the villages of Pullos, Tabbí, and Khurram.

"Kurruk, so called from the large amount of cultivated land (Pushtú karal, to cultivate) in the vicinity. It was first colonised in the time of the emperor Aurungzéb, but its salt hills were not quarried and resorted to by traders till about 1800 A. D. in the time of Sháh Zaman Sháh, Saddozai of Afghánistán. The lords of the soil are the villagers of Kurruk and Tappí, in shares of $\frac{2}{3}$ rd and $\frac{1}{3}$ rd, respectively.

"Bahádur Khél, the land of the Kurram clan of the Khattaks, now located north of the Teeree Towey (Tírfí Tauf) extended from time immemorial to the present Wazírí frontier. Some twelve centuries ago, according to local tradition, one Daresh, whose mother was a native of Kurrum, came from Tank in the Deraját to visit her. There were then four heads of families in the Kurrum clan. Daresh was admitted as a fifth and was awarded the waste lands on the immediate frontier. One Bahádur next came from Jordaud in the Kurruk (Khattak) country and settled with Daresh, who gave him half the lands. The Daresh Khél and Bahádur Khél, their descendants, are now lords of the soil within the limits of which the salt mines are situated, and divide equally among themselves the seigniorage allowed by Government. The Daresh Khél commenced trading in salt, it is asserted, immediately after their first settlement" (about 600 A. D.)

"The Khan of Teeree (Tírfí) has an agent here to watch his interests as he enjoys 10 per cent. of the gross collections, and also to give assistance to the salt and the district police generally.

"The very low rate of duty now obtaining at this mine was originally fixed for a variety of reasons,—first, because it was difficult of military approach from Bánnú owing to the Soordág (Súrdág) pass which leads to it being a difficult one to force in case of resistance from its warlike Khattak inhabitants and their Wazírí neighbours. Its salt had, moreover, from time immemorial sold at a low rate because of the distance and difficult routes traversed by its frequenters (Wazírís, Ghilzaís, Turís, Mattaní and Kharjun sections, Khattaks of Durra, Upper Bangashes and Bannúchis), and came at length to be considered the perquisite of the Wazírís and other western tribes, for, notwithstanding its cheapness, the habitués of the neighbouring mine of Nurree (Narf) never resorted to it before our rule, nor do they now. For these reasons, and because his doing so would in no way affect the trade either for good or evil, Major Reynell Taylor fixed the low rate (now obtaining) at this mine. It would, he remarked, keep^d things as they had ever been,

and prevent, until a fort should be built at Bahádur Khél, a coalition, as in February 1850, of Wazírís and men of Bahádur Khél and Dareesh Khél against Government. Again, the Bahádur Khéls were at that time and for some few years after in but nominal subjection to their chief, Khwaja Mohamed Khan, whilst their village held the approach to the mine." Captain Plowden notes. 'Captain Cokes' writing in March 1853, that this village was formerly noted throughout the whole district as the refuge of all thieves and murderers in the vicinity and the most *yagi* (lawless and independent) village in the country, not having for years paid any revenue, but he adds that the presence of a fort had made the people as well conducted as those of any part of the Kohát district, and converted them into regular revenue-payers. A carriage road' [? Gun Carriage] now 'runs through the Soordag (Súrdág) pass, and the Wazírís have imbibed a wholesome respect for a Government which has been stable and powerful for over twenty years, and have settled down into submissive subjects and peaceable neighbours, whilst a fort has been built at Bahádur Khél, and is held by detachments of Native Infantry and Cavalry."

Method of quarrying.—There are two methods applied in working the Trans-Indus quarries. At Jatta, Malgheen (Málgín), and Nurree (Narri) gunpowder is used, and the salt is given to the merchants in irregularly shaped pieces, whilst at Kurruk and Bahádur Khél it is obtained in slabs, detached from the rock by pick-axe and wedge without the use of powder. These slabs are called 'tubbís' or chukkis,' generally the former.

The tools used by the miners or quarrymen are, a pick sledge called '*koowar*,' 12 to 20 seers in weight, a smaller pick, '*soolák*,' a crow or jumper, called '*jubber*,' a needle for the blasting bore, '*sik*,' a spoon to clear the borehole, '*kurrundi*,' and a hand barrow called '*bangai*.'

The method of cutting the salt by fresh water is not in practice anywhere in these quarries; possibly it might be adopted in some places, but would require engineering contrivance.

Vault-shaped quarries.—Where gunpowder is used, the quarries are usually worked in the shape of a vault, sloping downwards at an angle of about 60°. The vaulted shape of the cutting in the salt-rock and overlying bank of *débris* is to give some security against falling in, and the sloping position is chosen to give stability to the *débris* and waste salt which had been filled into the empty space, created by the preceding excavation. The quarrymen cannot afford to remove a large quantity of the overlying *débris* at a time, and thus lay bare a large surface of the rock-salt upon which to work, and having to work successively, they just take as much *débris* away as will enable them to go on with the salt excavation for the time being. When they have excavated deep enough to make the removal of the salt difficult, they start afresh from above, commencing by throwing the overlying *débris* down into the hollow which they have left. By the time this hollow is filled, a certain surface area of rock-salt is again laid bare, having the shape of a ring segment from 4 to 20 feet broad, extending round the margin of the former vault. The area being ready, the excavation of the rock-salt is again taken up. A cutting is first made along the new inner boundary by means of the pick-axe, and then blasting is commenced. A blast takes off about 20 or 25 maunds of salt, and as the blasting proceeds, the cutting is carried ahead along the inner wall so as to form a fresh vault gradually as the old vault disappears; the face of the *débris* which had been filled in is laid bare, but remains standing, owing to its sloping surface, down which the road leading to the bottom of the quarry is carried. Had the excavation been worked down vertically and the *débris* been thrown into the previously excavated space when the salt was removed by the new working, earth-falls would occur from the face of the *débris*.

To this type of quarry, the general features of all, more or less, approach. Where the 'heading' is more than average, we even find real mines on a small scale, though never without daylight, whilst with exceptionally little *débris* the quarries are more open with a larger working surface.

The excavation of salt without blasting powder.—At Kurruk and Bahádur Khél the rock-salt is excavated without the use of blasting powder, the preference given by the traders to the old form of slabs, (called *tubbís*)* got by pick and wedge, seems to have prevented the introduction of gunpowder at the above-mentioned quarries. The slabs are all of an equal weight, ($1\frac{1}{2}$ maund Sikh weight), thus saving the necessity to weigh the salt, mere counting being required, besides some check to prevent the *tubbís* from being made too large.

The *tubbís* are flat, square slabs of 13 inches breadth and 4 inches thickness, their formation being aided by the stratification of the salt. The men ingeniously arrange their working places so that all the slabs are broken off in the line or plane of stratification, the space worked upon being from 10 to 20 feet in length and of an equal breadth measured down the slope of the bedding.

The most convenient localities seem to be those where the stratification of the salt dips at an angle of 45° . The working surface being prepared, the men begin by making channels with their short-handled picks of hammer-like form, so as to cause the isolation of a number of squares over the surface, separated by channels 3 inches wide and 4 inches deep, the latter equal to the thickness of the slabs. The pick-axes have heads of 3 seers in weight and cut remarkably well, or else the salt must be comparatively soft. I certainly would not have expected such quick cutting if tried at one of the Cis-Indus mines. From the mode of working, the channels get narrower as they penetrate, whence the slabs have sloping or bevelled edges. It is at the pleasure of the workman to finish the channels over the surface and thus have all the slabs ready for breaking off, or else to get one slab after another ready for

* It is curious to observe the predilection that seems to have obtained from remote times for salt in the form of blocks having some prescribed form. Here it is cut into *tubbís*. At the salt mines of Abyssinia, we read that blocks of it pass for money, and that at Toudem in the Sahara it is carried from the mines in a form resembling *tubbís* also, while even at the Wieliczka mines in Poland, barrel-shaped blocks are prepared for transport. Lumps or blocks of salt are said to be preferred by the Afghan herdsmen, who take the salt from Bahádur Khél for their cattle to lick.—A. B. W.

separating. The breaking off is very easy: a small, round, pointed iron is used as a wedge and driven in at the base of the slab by the aid of one of the hard boulders to be found in many parts of the country; the slab breaks off after a few strokes. By advancing the upper rows of slabs more quickly, the men can obtain convenient steps for themselves to stand upon and to move up and down to and from the working places. A tubbī seldom breaks, and from long practice, their size and weight becomes very uniform. If there is no connivance with the merchants, it is not the workmen's interest to make the 'tubbīs too large, for the larger the size, the more labour they cost.

In Captain Plowden's manuscript, the time required for excavation of the tubbīs is given thus (from Mr. Carne)—An isolated tubbī is got out in 25 minutes, a second one alongside it in 17 minutes, by one man, but it is not said how many sides were cut in each case. It was said at the quarries that a man can get out 16 or 20 tubbīs in a day, and from the method pursued, it follows that the labour of cutting out a single tubbī is twice as great as that required for cutting one among a lot.*

DESCRIPTION OF THE FIVE WORKING QUARRIES.

Jatta quarries supplying the depôt of Ismaïl Khél.—The quarries and salt outcrops of Jatta may be said to extend over a space half a mile long and a quarter of a mile broad. They belong to an inlier stretching east and west, enclosed on three sides by limestone ridges and opening on the fourth or eastern side to the valley of the Ismaïl Khél river which crosses the inlier. The highest hill is to the south. The distance of the Jatta quarries from the depôt at Ismaïl Khél to the north-west is three miles, and the road is extremely bad; that village, however, is only half a mile from the Bánnú and Kohát road, which, being a good one, is of

* In the Cis-Indus mines, a similar method, though not exactly the same, was in vogue before the introduction of blasting (shortly before or after 1860). Channels were cut into the face of the salt-rock so as to expose a rectangular block of several maunds in weight with one side adhering. Along this side two or three holes were made, into which were forced heavy pick-axes called '*Aswras*,' which received heavy blows until the whole block broke off.

immense benefit to the traffic. It is to be regretted that a good road has not been made from this to the quarries.

At the time of my visit (January 1874) there were nine different quarries at work, and at six more places the salt was exposed; all the quarries were situated at the interior slopes of the enclosing ridges. The number of quarrymen was 100, and each had on an average 90 square feet of horizontal rock-salt surface to work upon. The amount of débris overlying the salt is in several places very great. It may be fairly said that the amount of salt excavated in each quarry is on an average not equal to twice the amount of débris which had to be removed. Six of the quarries at work were of the kind described as vault-shaped. There was one very large quarry measuring 150 feet along the floor, and exposing a salt wall of 50 feet in height, with from 20 to 50 feet of débris over it.

This wall was concave, almost semicircular, but only slightly overhanging, so that the débris was kept with difficulty from falling down. On a second visit after a fall of rain and snow, I found much water accumulated in this quarry which had to be baled out; the quarry is situated at the south-western side of the valley. The other five quarries of the same kind were of various dimensions, from 25 to 125 feet in length, and from 10 to 40 feet in depth. The three remaining quarries differed from the usual form.

The working surface of one consisted of a succession of steps along the base of a vertical salt wall 100 feet in length and 50 feet high. For half the length the quarry was temporarily closed by a great down-fall of débris from above.

A less significant place near it had a working surface of 20 feet by 10 feet.

The last quarry was of rectangular shape, forming a pit of 50 feet length, 30 feet breadth, and 15 feet depth in the salt. To expose this large surface of rock-salt a heap of débris 30 feet high had been removed.

A salt outcrop over one of the quarries shows the salt stratum to have at that point a thickness of 100 feet, but as the bottom of the salt has not been reached, its total thickness may be much greater. There is some stratification seen in the upper part of the salt, but below in the quarries, it is, as a rule, compact, without any trace of stratification, though this would probably be difficult to perceive from the purity of the salt and quantity of marks of the pick. At one place there are apparent interstratifications of soft sand and clay, but these were also found filling cracks extending to the surface from which they could be filled. The apparently anticlinal arrangement of the salt here would lead to the supposition that where the quarries are, it is nearly horizontal. This Jatta locality forms an exception to most of the others in the absence of springs.

Malgheen (Málgín).—The salt quarries here are situated in a range of hills at a distance of fully four miles southward from Málgín, and on the left side of the Teeree Towey (Tírí Tauí) river. The northern side of the range is occupied by an almost vertical ridge of limestone and sandstones; below the limestone comes red clay, and under this the gypsum and salt group stretches from east to west, with the river on the south. The total length of the ground over which the salt outcrops occur is three miles. At the eastern end opposite to the village of Zertungí are the old Zaino quarries, and at the western end above the village of Saya (Séya) are the quarries of Malgheen (Málgín) from which salt is raised, those of Zaino being closed.

These Malgheen (Málgín) salt quarries are more difficult as regards supply than those of the other dépôts; the space they occupy is not more than half a mile long and a quarter of a mile broad, the average height above the bed of the river being from 300 to 400 feet. The number of old quarries is so great, that with difficulty places are to be found where, within reasonable depth, remaining patches of rock-salt can be dug out. The salt in these quarries, except near the top, showed little or no signs of stratification, but at an outcrop east of the working

quarries almost horizontal lines of stratification were observed, and a thick regular band of gypsum parallel to the salt rested upon it. From this and the general appearance, the salt about the quarries may be considered, either horizontal or slightly inclined to the north. The amount of débris about the quarries is very great, and the whole ground seems already so worked over that no continuous supply of salt can be expected from any of the openings.

In January 1874 there were thirteen different places of excavation at work. Of these eight agreed in construction with the vault-shaped form of quarry which is specially adapted to a place where such a great mass of débris exists. Two of these vault-shaped quarries had just been started afresh from the top, the space within the former vault had just been filled with débris, and more of this was being removed to clear the necessary surface of rock-salt. The other vaulted quarries had working surfaces from 20 to 50 feet in length and from 4 to 10 feet in width. In one of the quarries earth and débris not only limited the salt wall on both sides, but appeared also behind, so that evidently the last remaining piece of salt within reach was being worked out. The wall leading to the salt through the surface débris was in a most dangerous state and ready to fall in.

The largest of the vault-shaped quarries measured 50 feet long at the base and 10 feet broad; it was connected with some caves, the remains of other excavations. A road led through these caves by which bullocks brought up the salt from the working; the salt wall *in situ* was about 60 feet high, whilst the heading reached at one side up to 100 feet above the bottom of the quarry. Notwithstanding the large exposure of the salt, no distinct stratification could be noticed, and large cracks were seen in it filled with clay or débris. A man had been killed here by the fall of an overhanging bank of the latter a few days before our visit.

Another of these vault-shaped excavations had all the appearance of a mine; it had been carried out at an angle of 45° into the hill side for

40 feet, and the detritus rose 40 feet also above its mouth. This was situated east of the excavations previously mentioned. Besides these and workings which followed the standard method, there were places worked in a different way, and exhibiting still more difficulty in obtaining the salt.

At one of these the men had found only two small pieces or veins of salt, one 6 and the other 12 feet thick ; both were extensively enveloped in débris ; they appeared at the bottom of a well 40 feet deep, which was liable at any time to fall in upon the workmen. At another place a single man was working in a most dangerous hollow at the base of which mere blocks of salt were embedded in the debris. Another excavation was worked so as to leave rather a convex wall of salt. This unusual shape was owing to the peculiar outline of the débris towering above.

Further at the bottom of a great crater-shaped hollow in the débris of at least 80 feet in depth there was a regular tunnel driven into the salt. It had two entrances, and was about 50 feet long and 10 feet by 10 feet wide. The men worked without lights, although it was almost perfectly dark in some parts of the tunnel. However their workings resemble real mines they evidently object to work with lights.

The most perfect mine was seen on the south slope of the hill towards the Teeree (Tīrī) river ; its mouth was 10 by 20 feet, and it went for about 50 feet into the hill. Its height and width within were from 20 to 25 feet. There was very little salt to be seen, the débris appeared almost everywhere, and the place was dangerous enough, yet not more so than others.

How deep the still unworked portion of the salt extends here is a mere matter of speculation. I have no doubt it extends a good depth further than can be seen, and the bottom has not been reached in any of the workings.

Thus it appears that, under the present system, the thickness of the whole salt deposit is gradually diminishing through excavation of the

upper strata, whilst the mass of débris overlying the whole surface is becoming thicker and thicker at the same rate from the addition of waste salt. Instead of the overlying 'heading' being once for all removed to a distance, it is lifted and shifted over and over again in the course of many years.

That these Malgheen (Málgín) quarries are in difficulty as regards the salt supply is further evident from the small amount of working surface. An approximate estimation of this in each of the thirteen quarries or mines above enumerated gave a total working surface of 3,000 square feet only. The number of workmen was 100, so that each had only on an average 30 square feet to work upon, whilst at the Jatta quarries there were 90 square feet for each man.

The annual production of the Malgheen (Málgín) quarries is about the same as of those at Jatta, or in round numbers one lakh of Síkh maunds.

Nurree (Narí).—The Nurri depôt is, like Kurruk, a second rate one, only intended as a kind of reserve for Jatta, where the necessary supply of salt could not well be obtained all the year round. During the time of our visit the trade at Nurree (Narí) was very slack.

The quarries are situated on the northern slope of the hills south of the village of the same name; the distance between the quarries and the depôt is only a mile.

The salt outcrops extend over a length of two miles, but in order to facilitate the guarding, the quarrying has been confined within a space of half a mile long and several hundred yards broad; there are several large crater-like hollows of more than 100 feet in depth, the sides of which exhibit the salt in many places. Here and there the men had cleared off the débris and begun blasting: most of the working spaces being 20 feet broad or less. There was very little salt accumulated, and very little recent work done. The few quarries were all open, the amount of débris not being considerable, and the salt surface was more than was required. The most troublesome part of the work was left to the merchants: they

had to bring their cattle over the most difficult pathways on and along the sides of the deep crater-like hollows to reach the quarries, whence they had to remove the salt and bring it down to the depôt at Nurree (Narí).

The whole thickness of the salt seam, as far as was actually visible, appeared to be about 200 feet, and over the whole of this thickness there was scarcely any salt seen that would not have been saleable, the salt here being generally considered of first-rate quality. The place lying high, there are no springs apparent in the salt.

Kurruk.—This, like Nurree, is only a salt depôt of minor importance, serving to supplement Bahádur Khél. As already stated, the salt is excavated in the form of slabs or '*tubbs*,' and débris has in some places to be removed in order to approach the salt, the inclination of the stratification, too, generally sloping into the face of the hills at angles up to 40° and 45° considerable excavation has to be made to expose places favourable for the *tubbi* system of working on the upper surfaces of the beds.

The outcrops are traceable for some hundreds of yards along the indented and eroded outcrop of the gypseous series. The mineral is more pure than the average at Bahádur Khél, and is said to be heavier; it contains numerous blotches of transparent salt (*shishi nimuk*). The exposures vary from 20 to 40 feet in height, and some of the quarries are worked into the salt below the local level of the ground.

The extent of the quarry ground may be from one-quarter to one-half of a mile in length, and a few hundred yards in width, with a deep heading of gypseous and clay débris over nearly the whole of the ground. Springs of water occur in some of the workings situated at low levels, and large pits in the salt or open quarries had become half filled with clear saturated brine. The trade at the place did not seem very brisk, though apparently larger than at Nurree (Narí). The distance from the salt depôt at the village of Kurruk is less than a mile, most of the road lying over the sandy bed of a river which has to be crossed.

Bahádur Khél.—The quarries of Bahádur Khél are situated in the richest outcrops of the whole Trans-Indus region, these exceeding by far any of the outcrops in the Cis-Indus Salt Range. These outcrops extend over fully four miles in length, with a breadth of from a quarter to half a mile, between two ridges, running from east to west. In the eastern half of this tract the salt shows in a great number of outcropping exposures, while the western half is almost entirely of naked salt; patches of gypsum or earth to conceal it being rare. The road leads over salt, and the brook of saturated brine which drains the valley flows westerly over pure salt-rock, part of the salt surface being cut down by the water to the level of this stream. The salt which has retained its higher level forms embankments on either side of the valley, or rises in hills within it. Two of these are remarkable for their size, being about 200 feet high, and standing near each other in the middle of the basin (see Frontispiece). The strongest dip of the salt is to the north; but there are indications of an anticlinal structure. Where the salt is most exposed, it has a breadth of over 1,500 feet, with an angle of inclination that gives a thickness of at least a thousand feet, and as this only includes what is visible, the actual thickness there may be much greater.

The larger portion of the salt consists of pure workable strata, a small part only being unfit for excavation. I measured on the western of the two large salt hills mentioned a continuous series of workings through 140 feet of salt strata. Besides this there were many other workings in the same line of section, as well as in other parts of the valley, near where it is crossed by the Kohát and Bannú road, this having apparently decided the choice of locality. The salt, considered unfit for working, was that mixed with a larger proportion of the same bluish clay which, more or less, pervades almost all the salt layers of this locality. The clay is quite harmless, and it is only the larger quantity of it occasionally locally present which hindered the excavation of certain of the strata where purer layers were to be found close at hand; no other ad-

mixture with the salt was noticed. The taste of the salt is everywhere the same, and no traces of foreign salts could be found.

The salt is obtained in the form of 'tubbis' previously described; the quarries have accordingly all to be chosen, so that the working surface is parallel to the plane of stratification.

The number of the quarries at work must be at least 30 (60 according to Mr. Carne: Captain Plowden's Memo.), and there are a great many more abandoned, most of which are filled with brine from springs which are said to be unusually numerous in this salt.

The number of quarrymen is said to be about the same as at Jatta and Malgheen (Málgín), namely 100, but there should be more to produce the same outturn, because the tubbí system requires more labour than blasting, but, on the other hand, much labour is saved by the absence of débris, which is so troublesome at other localities.

The main road from Bánnú to Kohát (following a newer course than the one indicated upon the map) passes through the quarries, and by a capacious tunnel 500 feet in length issues from the valley, passing beneath the ridge which closes in the quarries to the north. Not far from the opening of the tunnel in that direction is the Mundí or depôt, with the Serai for the merchants and the salt establishment, about one mile from the quarries. Two miles further are the fort and town of Bahádúr Khél.

17. *Excavation fees.*—The rates for excavation fees are as follows :—

At Jatta and Malgheen (Málgín) about 1 Re. for 24 Sikh maunds,* or $\frac{3}{4}$ anna per maund.

" Narri	"	"	1	"	32	"	$\frac{1}{2}$	"
" Kurruk and Bahádúr Khél	"	"	1	"	16	"	1	"

A maund is equal to two tubbís.

* The Sikh maund is said to be equal to 1 maund 12 seers British. The British maund, for the convenience of non-residents of India, may be stated as equal to 80 lbs., and to contain 40 seers.

The salt is slightly dearer at the last two places on account of the method of extraction, and at Nurree (Narri) it is cheaper than at any of the other quarries, owing to the readiness with which the salt can be extracted.

The trader has to pay for one maund of salt in the shape of tubbís one anna, in irregular pieces at Nurree (Narri) half an anna, and at Jatta and Malgheen (Málgín) two-thirds of an anna; the average fee for the excavation of the salt is thus between half an anna and an anna per maund. This excavation fee is quite distinct from the price which Government takes for the salt.

Cost of the salt at the five working places, exclusive of the excavation fees.—This is fixed as follows:—

				R.	A.	P.
At Ismail Khél the price of one Sikh maund is	...	...	...	0	4	0
„ Malgheen (Málgín)	...	...	...	0	4	0
„ Nurree (Narri)	...	...	...	0	4	0
„ Kurruk	...	...	...	0	3	0
„ Bahadur Khél	...	...	...	0	2	0

N. B.—Kábulí rupees are taken at the rate of $12\frac{1}{2}$ annas to the rupee, 5 of the former being approximately equal to 4 British rupees.

At the two latter depôts only a few of the ‘tubbís’ are weighed to check their size, each, when properly cut, weighing 20 seers (Síkh), the rest are merely counted as so many half maunds. No sale of less than half a maund takes place, and where irregular pieces of salt are sold, each sale must be a multiple of 5 seers, or $\frac{1}{4}$ th maund.

Cost of transport of salt per maund.—The cost of transporting one maund of salt varies from one anna for eight miles to one anna for sixteen miles distance, according to the quality of the road. The excavation costing on an average less than one anna per maund, the expense of excavating one maund would be equivalent to the transport of the same weight over a distance of from six to eleven miles.

20. *Depôts.*—There are five depôts for the sale of the salt taken from quarries, not always in the immediate neighbourhood, thus—

1. Ismail Khél,	supplied by the Jatta	quarries.
2. Malgheen (Malgín)	" "	Saya (Séya) "
3. Nurree (Narri)	" "	Nurree, (Narri) "
4. Kurruk	" "	Kurruk "
5. Bahadur Khél	" "	Bahadur Khél "

REVENUE.

Statement of the salt receipts and expenditure during the fifteen years, 1857 to 1872, and during the one year 1871-72.

				1857-72.	1871-72.
				Ra.	Ra.
Collection	...	...	...	12,48,961	78,027
Malkhana and contingencies	...	...	...	1,49,675	10,154
Cost of establishment	...	...	...	2,54,927	17,465
Nett profit				8,44,359	50,408

The average nett profit during the fifteen years was Rs. 56,290.

In the last financial year 1871-72, the net profit was below the general average, i. e., Rs. 50,408 only.

Description of some old mines and outcrops.

1. *Sireemeyla* (Sirímela).—One mile from this village on the northern slopes of the hills between it and Weejosum (Wijúsum) salt exposures were shown to us in two places near each other. One was purposely concealed by brushwood, the other was higher up near the escarpment of a gypsum hill, and from it I was able to break off a sample. The salt was of good quality; it appeared as if excavation had taken place here, but this was negatived by the native inhabitants of the place. Salt may be supposed to extend for half a mile here in the direction of the range, and with a width of 300 yards. The higher exposure is about 200 feet above the stream over the right bank of which it occurs, and the locality does not appear very favourably situated. The height above the valley not being great (and there appears to be a large mass of débris,) the dip of the salt could not be discovered.

2. *Lachee* (Láchí).—Close to the west of the village of Lachee (Láchí) on the Kohát and Bahádur Khél road, quarries in salt have been worked in former times, but have long been closed (from the statements of old people of the village probably about the year 1830 A.D.) From their occurring so near the road, these quarries are of some interest, and because they are nearer to Kohát than any of the others. They occur close to the foot of a limestone-covered hill, and over a rising ground covered by gypsum, hollows in which indicate the sites of the old quarries. In the valley of a small stream crossing this gypsum a weak brine spring issues. The hollows mentioned are very deep, yet no salt crops out in them. Concerning this locality the following information was collected :—

An old miner of Lachee (Láchí) village, stating his age at 71 years in January 1874, said, the salt quarries were worked in the life-time of his father, and that he also had cut salt in them.

The salt was sold at the Affreedee (Afrídí) pass to Pesháwur for Rs. 2 per maund, but was not carried across by the Láchí people to Pesháwur, they being afraid of the tribes in the pass.

The quarries were covered with a heading of clay, gypsum and débris higher than the two-storied bungalow of Lachee (Láchí) fort, even 30 guz (? cubits).

The quarry he worked in was about the size of a room in Lachee (Láchí) bungalow, and the salt was about as high as a man's stature all round. A spring filled the lower part of this quarry, but there was still salt below.

The water did not burst up in every place, and he thought it might be led to the river (that is, that it was higher than the stream to the south).

The salt was good in every way like that at Jatta.

The quarries were closed about forty years ; they had been worked for forty years previously, and were abandoned on account of their depth and

the difficulty of managing the thick heading of débris.—From notes made as the man spoke.—A.B.W.

As the site of the quarries is scarcely 100 feet above the level of the plain to the south, the surface of the salt may be but little higher than the latter, and deeper excavation would require special precautions against the influx of water. Whatever form an excavation here might take either by quarrying or a low level tunnel, it is certain that salt could be obtained here if desirable. The quarries which may have been considered exhausted as far as the art of the local workmen was concerned would not be so with superior means at command.

The space underneath which salt may be presumed to occur is about 200 yards broad and 500 yards long. It need not, however, be confined to this area, but may continue westwards beneath the gypsum in a position better suited for mining.

3. *Sdkhórbúgher, old mine or exposure.*—A mountain stream high upon the hills north of the Teeree (Tírí) valley works through red clay into a rib of gypsum, where it has an underground course for many yards, and being dry when visited, one was able to enter the mouth of the cave whence the stream issued. A salt surface of several yards was seen forming the left side of the cave chiefly, and traceable inwards as far as the mud allowed one to walk and as far as day light enabled it to be seen, *i. e.*, for 52 feet. The salt was of the usual character, dark in colour and part of it seemed to contain some gray clay. The place being high, a mine might probably be worked here, but the glen is very steep and narrow, and, as usual, approach over the belt of nummulitic limestone by the stream course is difficult and precipitous. The salt shows some lines of oblique lamination, dipping west at low angles.—A. B. W.

4. *Shákádrung.*—On the west side of this mountain at the head of a long valley issuing at Murdán Khél a concealed salt outcrop occurs among red clay and fallen gypsum. The quarries here were open when Mr. Carne wrote, but inconsiderable.—A. B. W.

5. *Thrtkanushpa*.—This is one of a group of old mines, and small exposures called by the general name Manzullí; it is a traditional locality under fallen masses of gypsum; only some saline *shór* or efflorescence is seen.—A. B. W.

6. *Thór-drung*.—A little salt is seen here under a steep declivity, almost a cliff of gypsum, 150 to 200 feet in height, over which lies much débris of green or gray clay. There are two spots, at one only of which the salt is visible; it presents the usual characters.—A. B. W.

7. *Tapá-drung*.—A hill of salt apparently, capped by gypsum, &c. Green muds or shales dip at low angles west by south to pass under the hill, and a 25-foot cap of gypsum and clay covers it. The salt crops round the northern side of the hill, and the appearance is that of an isolated patch of salt in the clay and gypsum, but appearances cannot be trusted, as slippage or faulting might be present in such a highly disturbed place. This hardly resembles any other locality in the salt region except in a very general way on account of the appearance just mentioned. The thickness of the salt exposed may be from 15 to 20 feet, and the bedding seems to vary from horizontal to a slight south-westerly inclination.—A. B. W.

8. *Bádhór-drung*.—A little dark gray salt is seen just beneath the gypsum, as if between this gypsum and gray clays, the salt dips with the gypsum showing about 10-foot of an outcrop. There seems no certainty of any large mass of salt here; the relations are very obscure, and the whole place is open to suspicion of slippage. This is the last of the exposures to which the name of Manzullí was applied.—A. B. W.

9. *Záwá-drung* is a small exposure of salt in a nullah entering the right side of one of the heads of a stream which joins the Teeree Towey (Tíri Tauí) at Sharki; the salt is covered by green clay, over which is apparently a large patch of gypsum, in which layers of gray clay occur irregularly.

10. *Soorthung*. (Sárthung).—On the northern side of this summit in a central ravine of the hills, are what appear to be old salt mines in

great vertical openings, showing an apparent thickness of 80 to 100 feet of salt under a 50 to 70-foot heading of shale or clay débris, with angular blocks of the local rocks; the salt is of a dark gray color, seems of good quality, and its stratification may undulate; some high dips to west and north-west were so indistinct that they could hardly be relied on. The gypsum, though seen near the place, does not now rest on the salt, and it is very possible that some of the gypseous clay called '*shoenkoura*' may have been the succeeding rock.

11. *Mírandí road*.—In a ravine where this pathway is about to leave the hills north of Totukki, amidst some gypseous and clay débris, there is a little salt, purposely concealed; it has a whitish-gray colour, and seems of good quality.

12. *Burburra, Scappah-drung*.—A deep khud here traverses much gypseous débris and red clay. In the main ravine and side nullahs huge masses of rock-salt are seen cropping from the banks for fully half a mile with an apparent horizontal arrangement and a thickness of perhaps over 200 feet. At one place there is an appearance as if a 50-foot band of the salt overlaid black gypsum; but as the latter might have slipped down, no weight could be attached to the observation; the salt is of good quality and of the usual gray colour. The whole place presents a most disturbed and shifted appearance, but as either a mining or quarrying locality, it can hardly be surpassed in this part of the district; it is also near the high road from Kohát to Bánnú.

13. *Bándá Surdág*.—In some of the small ravines about a mile east of Bándá serai and rest-house on the road just mentioned, small masses of salt are seen in contact with purple gray clay, greenish and red clay, and lumpy masses of black impure gypsum, all jumbled together and affording no instructive section.

14. *Drungí Bándá*.—Eastward of the latter locality, and north of this *bándá* or village, are some reputed old salt mines in dark coloured (upper) salt which show in about 10 to 15 feet outcrops close to a

mountain stream, and beneath dark gray and black bituminous gypsum. The stratification seems to be at a low angle inclined to dip northerly; close by are rotten alum shales and some sulphurous springs.

The locality is one of much disturbance and complexity, and the low level at which the salt is seen is against it as a place for mining.

Zgaruttí.—Two small exposures of salt are said to be known beneath débris on the southern slopes of Zgaruttí hill.

15. *Zaino or Zino quarries.*—These occur at the eastern side of the ellipsoid hill, within which the Málgín quarries are worked, but no workings are carried on here. At this locality going from west to east are six large crateriform hollows, which all contain more or less salt. The depressions are at least 100 feet deep, and must be drained subterraneously by channels probably leading towards the Teeree (Tírf) river through salt gypsum and débris. The stratification of the salt appears nearly horizontal, as might be expected close to the axis of an anticlinal curve, and that it was once all overlaid by gypsum appears likely from the quantity of this rock lying about in broken fragments. In one of the hollows, a salt outcrop, 50 feet high, showed a regular stratum of gypsum, 10 feet thick, overlying the salt. The upper beds of the latter appeared very black, but when broken did not smell as might have been expected. Large masses of the salt were found which would be of inferior quality as regards consumption. At some places lower strata of better quality were seen; by keeping to these lower beds, salt of sufficiently good quality might be procured at any time. Beyond the crater-like hollows salt appeared also in a small transverse ravine, and beyond that another outcrop showed on the hill side. This last is very near the top of the ridge, at least 700 feet above the adjoining river valley; thus mining ought to have good prospects here. The extent of the Zaino exposures is half a mile in the direction of the ridge, but the breadth is small. Quarries are said to have been worked here in former times, but there are no traces of them now.

16. *Nundrukkí* lies north of Húkaní mountains and north-west from Shukkurdárri. North of the village of Nundrukkí there is a large area of gypsum, on a commanding point of which a guard tower has been erected; near this is a crater-like hollow with a subterranean escape. North and east of it are two more such hollows, with ravines running into them; these also have subterranean outlets. The sides of the craters are all naturally 'dressed' by earth and débris, amongst which large vertical cliffs of rock-salt crop out. It is of the usual appearance and gray colour. A good deal of heading would have to be removed before safe quarries could be opened, but for mining operations the locality seems well suited; the salt here must be nearly horizontal; there is a fourth hollow of the same kind to the east, but the salt is not seen. The craters being 200 feet in depth, this thickness at least may be attributed to the salt. Around this place there are some smaller exposures: one, called Súrðand-drung, lies within a mile north-eastward in the same gypsum area, another near it is called Esho or Yeshu-drung. Another occurs south-west from the watch tower near the village Kurrár associated with a quantity of gypseous débris, and north-westward of the latter is still another small salt locality near the summit of Peer Goot (Pír Gút) Sír mountain.

17. *Dund, Durri-drung* is the name of a small salt outcrop which occurs in the range connecting Nundrukkí and Kurár Sír and on its southern side, below gypsum. The locality is two miles east of the village of Dand, and is sometimes called by that name. The quantity of salt is very small, and the locality unfavorable for excavation, yet quarries are said to have been worked here in former times.

A small quantity of salt was said to have been once exposed between this and the Turrillí ravine or Mittán pass to the east.

18. *Kurrár*.—A large exposure of salt occurs in the southern face of the hill below Kurár Sír, and a guard post has been built for its protection. The rock-salt has a thickness of 150 feet as far as it is shown by the outcrop, but this cannot be at all presumed upon as any limit of

its real thickness. One salt cliff near the guard-house is 60 feet high by itself. The salt is very pure; indeed, it is said that purer salt could be got here than at any of the other localities in the district. From what is seen the salt appears to contain only a minute proportion of the blue clay which forms the principal foreign ingredient of the salt at the western and other quarries. The uppermost strata only were here inter-laminated with thin bands of black bituminous salt; some other layers contained small fragments of gypsum. The salt is stratified and shows a dip to the north; it is either colourless or of a light gray tint. Some that had a reddish look proved to be only superficially coloured by washings from a red marl above.

The salt outcrops for half a mile along the hill side, and projecting spurs from this are formed of the overlying gypsum from which the presence of more salt within the hill may be inferred. By removing the débris very large quarries could be formed and mining could also be advantageously carried on, as the salt rises 150 feet above the adjacent gorge.

19. *Speena* (Spína).—There are here on the north-western side and to the west of a large expansion of gypsum several large open outcrops of salt, some of which discharge brine in considerable quantities as shewn by the thick incrustations of salt in the stream below the hill and to the northward. The salt undulates slightly, and shows strongly round the sides of semicircular hollows. It is of the same character as usual, and much resembles the Nurree (Narri) salt. The western exposures occur over the pathway in the pass of Kohneegá; on its north-eastern side, but at this place the rocks are all so much broken and disturbed that no relations can be discerned among the confused masses. The larger exposures would suit well for workings.

20. *Sirraikhwá*.—Salt is seen in two principal places here, both in cliffs, north and north-by-west of the village of the same name, and, as usual, overlaid by gypsum and débris. At the most westerly locality the salt has a face 35 feet high and dips north at 40°. Nearer to the

guard-house or *tápú* there are large crateriform hollows evidently formed by solution of underlying salt, and a considerable hill shows a strong salt outcrop presented to the west, and dipping eastward beneath gypsum and tertiary sandstones. The salt in this hill may be 200 feet in thickness. The stratification is plain, and from the manner of exposure appears as if nearly horizontal. Oblique lamination lines in the salt occur, indicating currents coming from a northerly direction; its general colour is white or gray, and its purity intermediate between that of the Bahádur Khél and Nurree (Narri) salts. The situation would be very favourable for any kind of working.

21. *Tápá-drung*.—Westward of the Kurruk group of quarries, there are several other outcrops, the place being known by the above name taken from a guard-house or boorj on the spot. The salt has the same general character as that at Kurruk; it dips to the north at 30° and 40°.—A. B. W.

22. *Gooroozi*.—There are numerous salt exposures from the village eastwards along a fault boundary between the gypseous series and tertiary sandstones; the salt is generally good, appearing in outcrops from 20 to more than 50 feet high, according to the appearance of the ground.—A. B. W.

23. *Záwá Álgud*.—Where this stream issues from a rocky gorge west-by-north from Gooroozi, great masses of salt are seen on the right bank and in adjacent nullahs: the exposure measured 560 paces across the strike, and the chief mass is about 80 feet in height; the salt is dark gray, like that at Bahádur Khél, but less laminated or more solid, and apparently more pure. A great deal of it was seen in perfectly naked exposures.

24. *Soordag (Sardág)* pass, or Thrukkah Álgud.—The salt here is near the southern mouth of the pass, and was traced along a faulted junction with the tertiary sandstones and red clays for 600 paces, being a few yards to a few feet in width; part of it is overlaid by gypsum

patches; the salt is nearly horizontally stratified, and the outcrops from 5 to 30 feet in height. This salt, dissolving under the atmosphere, covers itself with a layer of the clay which it contained; it is of the same character exactly as that at Bahádur Khél.—A. B. W.

25. *Sáppárrí*, a salt locality in the hills south-west of Bahádur Khél, close to the British Frontier. The salt was not seen, only a strong saline efflorescence, and it was said to have been concealed by a fall of débris. The place is just at the watershed between the Changôsh and the Bahádur Khél streams.—A. B. W.

Besides the above there are a few smaller salt exposures near the others, sometimes called by separate names; thus Lukki and Kótkullí between Sirraikhwá and Kurruk, where a little salt is seen.

Total outcrop.—If the working quarries be included with the localities just mentioned, the exposures will number at least 335, exhibiting, when approximately although very roughly estimated, 3,082,996 superficial feet of rock-salt.

Total quantity of salt.—If the above exposures of salt be supposed to have a thickness of only 100 feet, the quantity present might be estimated at 500 millions of maunds, equal to the present demand for 1,000 years, but this estimate would be unreasonably low, for, in attempting to calculate the quantity, we must remember that the area of at least all neighbouring ground in which salt is probably concealed should be included, and then it would have to be reckoned, not by square feet, but by square miles. The Bahádur Khél, all but naked rock-salt, is four miles long and a quarter of a mile wide, giving one square mile of area: the Malgheen (Málgín), Jatta, Bárbárra, Gooroozí, and Narree (Narrí) quarries may be taken at a quarter to a fifth of a mile each, but these are only some among many localities, so that an area of five square miles may be fairly supposed to represent the space in which rock-salt is pretty certain to exist (though it may really be much greater). The salt strata measure 1,000 feet thick at one place at Bahádur Khél, but taking the thickness for the

whole of the above area as only 200 feet, this would give an amount of 40 milliards of maunds, sufficient, after making a large allowance for waste, to last at the present rate of consumption for over 40,000 years.

With such a vast supply there is little necessity to speculate, for practical purposes, about the existence of further salt treasures below the great gypsum area of these hills, but it would be satisfactory, in a scientific point of view, to know whether the salt is, or is not, as continuous as the gypsum under which it lies.*

Waste of the salt by rain and in quarrying.—The average rainfall registered at Kohát Station between 1863 and 1873 was 17·12 inches, and at Bánnú 11·25 inches, averaging 14·19 inches. If we suppose the latter amount of rain to fall annually upon the exposed salt surface, and a saturated brine to result, 0·2 feet of salt will be dissolved annually, but taking only 0·15 feet instead, as the brine would not be quite concentrated, the conclusion is arrived at that 4½ lakhs of cubic feet of salt are annually dissolved and carried off by rain water from exposed surfaces, an amount equal to 742,500 maunds of rock-salt!

Much salt must also be carried away by subterranean percolation of rain water, as may be seen in the incrustations of numerous brine springs, so that it will be within the limits of probability to say that the annual waste by natural agencies is equal to twice the amount sold. Compared with this great source of loss, the waste now taking place at the quarries by throwing away the small salt seems insignificant, being, perhaps, annually not more than one-sixth of the amount removed from outcropping salt by rain.

* This question applies both to the Cis-Indus and Trans-Indus salt regions. In both the gypsum extends through the hills, but the salt may be supposed with much probability to have a lenticular disposition. Here and there it reaches an enormous thickness, apparently over 1,000 feet in this region, and up to 600 feet in the other, but in other places it may have altogether disappeared.

The theoretical supposition of the salt having been deposited from the evaporation of sea water, separated entirely or temporarily from the ocean, and thus collected in the deeper pools or hollows, will be found mentioned above.

With regard to the waste of the salt in quarrying, it is true that even a larger loss is taking place at these than at the Cis-Indus workings. At the latter, chips of salt above half a seer in weight are all used, but here pieces of 5 seers are thrown away, and all the sharp corners of the blocks are rounded off, as well as the very great loss which takes place in the manufacture of tubbís. While in all cases economy should be practised in both localities, the natural resources are so great, that there is no actual necessity for causing inconvenience to the traders or outlay to Government in order to avoid wasting the salt. The waste from small salt cannot pass beyond certain limits, and much more damage might be done by irregular mining and by careless quarrying. If the beds of good salt within reach are systematically consumed by either mining or quarrying without allowing whole strata to become practically useless from the accumulation of débris, or to be destroyed by access of water, &c., the damage done by rejection of small salt can well be put up with.

The traders to the Trans-Indus depôts use only open palm-leaf rope net-works (turringries) for carrying the salt in; by introducing the use of bags as at the Cis-Indus mines, the waste of salt might be at least reduced to the lower standard of the latter mines, but even this may be thought the less necessary, because the amount of salt cropping to the surface is so much greater Trans-Indus.

Although so much in excess as to make it seem wonderful how these Trans-Indus outcrops have withstood destruction during a whole geological age, they must in coming centuries melt down to the level of the water-courses, or become deeply covered with débris through the mere action of the atmosphere, the excavation and waste being at the same time continued or not, locally, as the case may be. Mining, instead of quarrying, would then have to be carried on, and it would then be time to think of economising the small salt.

Foreign salts.—No deposits of potassa or other foreign salts have been found overlying any of the salt beds of this region, yet this is no reason why they should not be supposed to exist. I have, however, carefully

searched at all the outcrops which I examined, but have never been rewarded by finding any, not even a trace of their occurrence, though a small deposit of the kind has been met with in the Cis-Indus Mayo Mines.

The salt is constantly accompanied by gypsum, yet only at a few places (as at Kurrár) small fragments of this mineral have been found enclosed in the salt itself, and it required analysis to detect the presence of this mineral. Neither has anhydrite been found associated with the salt except as very small crystals in the gypsum of Málgín. The principal impurity of the salt in this district is a bluish clay, which is, however, rarely present in sufficient quantity to prevent its being worked. The uppermost salt layers include, at most places, black laminæ containing bituminous matter and smelling of petroleum; and sometimes the ordinary salt when of a slightly darkish colour, as, for instance, at Jatta, has the same smell when freshly broken, though but slightly. In one quarry here a layer of black earthy salt occurring in the midst of good salt was highly bituminous and smelt strongly of petroleum; it contained also pieces of iron pyrites and calcareous marl. On dissolving some of the upper bituminous salt of this Jatta locality, a residuum was obtained of a brown bituminous sand which burned white before the blowpipe, yet retained a slight petroleum smell. There was evidently not sufficient oil in the salt to appear as such on the water in which it was dissolved.*

* In Karsten's large work on salt (previously referred to, p. 37, &c.,) such reference is made to the occurrence of mineral oil with rock-salt as would appear to show that he was certain of some relation existing between the two. Thus at page 491, speaking of modern Italy, he says, "the occurrence of earth-oil in several parts of the country combined with its geological constitution to lead to the expectation of finding brine springs and even rock-salt, though neither were yet known." Again, at pages 506-7, he gives the result of borings for rock-salt at Marmarosch in Hungary. "The rock-salt is covered by 31 feet 8 inches of clay of various quality, 3 feet of which immediately overlying the salt has a strong bituminous smell, this bituminous clay being always the immediate covering of the salt." Another boring gave 31 feet 7 inches of strata overlying the salt, the layer of bituminous clay next to it being 5 feet thick, and the lowest 2 feet of the clay being saline (p. 587). He also says that all over the region of earth-oil and naphtha at Baku, &c., on the Caspian Sea there are also brine or salt springs.

At the Saya Malgheen (Séya, Málgin) quarries the upper layers of the salt alternated with black bituminous gypseous rock at one place, which contained small but beautiful crystals of anhydrite in transparent, colourless, rectangular prisms.

Geographical area of consumption of Trans-Indus salt.

Eastwards of this salt region the river Indus Customs line forms a great boundary confining the consumption of the cheap Kohát salt in that direction and separating its distribution from that of the Salt Range which pays a tax of Rs. 3-1 per maund. Kábul gets its salt from Bahádur Khél by the most direct route through the Koorum valley, which is reached in a few marches from Bahádur Khél by various rugged routes. Most of these lead over the (Manzullí) range of hills north of that place, then turning westward until the Koorum river is reached; from this part the traders follow the stream north-westward, others proceed westward and south-westward through the Wazírí country, the carriers being themselves Wazírís and Ghilzaís.

The most western limit said to be reached by this salt is lake Alistád* in the Ghilzaí country, south of Ghazní, at a distance of nearly 200 miles from Bahádur Khél. I learned, however, from a native of this Alistád region that this salt was carried further still in a westerly direction and down to Kúndabar. At this distance, however, it was very dear, and equal in price to ghee, wherefore many people could not afford salt, and some used an impure efflorescence instead. He also said the Alistád lake was not a salt lake.

Another portion of the Bahádur Khél salt is carried southward *via* Bánnú into the Deráját, or country between the British frontier in that direction and the river Indus preventive line. For this route, too, the Kurruk salt is chiefly reserved, going by a more direct road past Sheik Búddá mountain to the south, but some of it is also allowed to go to Bánnú, and thence to the west along with the Bahádur Khél salt.

* Captain Flowden's memorandum. The name of this lake in the recently issued map of Turkistan is spelled Ab-istada.

The rate charged by Government at Kurruk being 1 anna, and at Bahádur Khél 2 annas, less than at the eastern quarries, salt from the west is forbidden to be carried in the direction of the eastern sources, a prohibition which ought not to be difficult to maintain, as the distance from Bahádur Khél to the nearest open quarry eastwards, that of Nurree (Narri), is sufficient to counterbalance the difference in the rate by the increased cost of transport.

The two western sources supplying the countries to the west, south-west, and north-west, the three eastern localities are reserved for the countries to the north, north-east, and north-west. The Jatta salt is taken northwards along the Bánnú and Kohát road. The salt from Nurri takes the same road. Camelmen, as a rule, are supposed to go to Nurri for their salt, the road being better, while bullock-and donkey-men go to Jatta on account of the three miles of bad road between the quarries and the depôt being more accessible to their beasts of burden.

The salt having reached Kohát and supplied its wants, is taken on by the Affridí pass to Pesháwur, a road for the use of which Government pays a 'black mail' of Rs. 12,000 annually to the Affridí tribe, whose country stretches like a peninsula of hills into the British territory. Of the surplus remaining after supplying Pesháwur, a part is taken west by the Khyber pass, as far as Ningráhár, not generally reaching Kábul, but being consumed in the provinces lying on the way thither. Another part of this salt from Pesháwur is carried northwards to Bajour, Swát, &c.

Malgheen (Málgín) possesses a salt road of its own, called the old "Drung-ka-rásta," which, avoiding the Affridí pass and country, leads up the right side of the Indus, crossing the Mirkálán pass into the lower part of the Pesháwur valley.

From the north of the last named pass, some of the salt goes to Pesháwur, but the larger quantity to the north-east, Yusufzái, Bonér, &c., also across the Indus near Torbeyla, beyond the preventive line, to places whence no competition with the high taxed salt of the Salt Range could take place.

This road from Malghem (Malgin) is a mere track, but is important, as all the northern salt trade would have to traverse it in case of the Afridis closing their pass.

The distance from Bahádur Khél to Kábul being 160 miles, to Lake Alishá, 180 miles, and to the Hindú Kúsh, 200 miles, the consumption area of the Kohát salt region may be said to be included within a radius of 200 miles, this limit being probably not reached in all directions, notably to the east, where the circle would be nearly intersected by the preventive line, while it is exceeded in the Dérájat and Sind direction. Reports say the salt goes as far as Kándahar and Balk, which would be much more than 200 miles, but it is doubtful if any considerable amount of the salt reaches these distant places. The whole area through which this salt is distributed may be equal to 60,000 square miles.*

* None of the salt of this country, nor any of that from the Salt Range, appears to reach the Yarkand territory, though some of the latter occasionally penetrates as far as Ladak, but not beyond.

This statement is made on the reply to a question contained in one of the last letters written by the late Dr. F. Stoliczka, under date Káfilong, June 13th, 1874, from which the following is extracted:—

"Pure salt in small cubic crystals sells in the Yarkand and Kashgar bazaars at the rate of 1 pice per pound, and common salt (efflorescence salt for beasts) at the rate of 7 annas for a donkey-load, somewhat over two maunds."

The lowness of these prices would seem to be sufficient reason for the Salt Range salt not being carried farther than Léh, but even the much cheaper Trans-Indus salt, though it supplies the Yusufai country and hills north of the Pesháwar valley, does not appear to be worth carrying into Kashgar through the Jálálábád pass, said to be practicable for laden camels the whole way.—A. B. W.